PRELIMINARY ASSESSMENT OF EFFECTIVENESS OF PRECUT TECHNIQUE IN CONTROLLING

TRANSVERSE CRACKS FOR ASPHALT PAVEMENT IN INTERIOR ALASKA

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TRANSVERSE CRACKS FOR ASPHALT PAVEMENT IN INTERIOR ALASKA

A
THESIS

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Abstract

Transverse thermal cracking is one of the most common pavement distresses on asphalt pavements in cold climates. Transverse cracks are costly to maintain and unpleasant to drive over. The State of Alaska Department of Transportation and Public Facilities must seal cracks every summer to prevent further road damage from occurring. A simple solution that is gaining support is the precut technique where saw cuts are installed perpendicular to the road centerline shortly after construction to help relieve thermal stresses that cause cracking. This technique has effectively reduced the effects of natural transverse thermal cracking in other states as well as in Fairbanks, Alaska. This study investigates two road construction projects that include precuts with variable factors including three precut spacing intervals, five precut depths, and five pavement structures. Costs to install precuts are also compared against the cost to maintain a section without precuts in a preliminary cost effective analysis. Crack survey data from both projects have revealed that precutting does reduce transverse thermal cracking. Shorter precut spacing, placing precuts where natural cracks existed prior to construction, deeper precuts, and stronger pavement structures provided the best results. Further observations and more accurate cost data are recommended for an absolute determination of cost effectiveness.

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Chapter 1 Introduction

1.1 Problem Statement

Low temperatures in Alaska can induce extreme tensile stresses and overcome the internal strength of asphalt in pavement causing a thermal crack to form. Natural thermal cracks expose more asphalt concrete to the environment and allow water and deleterious material into the void and subbase below causing further damage to the pavement structure. Maintenance in the form of crack sealing is then generally required to extend the life of the pavement and provide a more comfortable ride to the user. Although precutting into asphalt is a relatively new technique, the idea has been around for a very long time and has been in practice in rigid pavements for decades. Precuts may help dictate where thermal cracking will occur in flexible pavement, provide a smoother ride, and reduce future maintenance costs.

Precutting joints into new asphalt concrete is a technique used and experimented with by multiple agencies. The Alaska Department of Transportation and Public Facilities (ADOT&PF) has used the technique on very few projects. This study investigates a precut technique for eliminating or mitigating the adverse effects of transverse thermal cracking in asphalt pavement. Some factors that may affect the precut effectiveness include precut depth, precut spacing, and the pavement structure to which the precut technique is applied.

1.2 Objectives

The main objective of this study is to determine if precutting on asphalt concrete in cold climates will inhibit the creation of new natural thermal cracks. Intermediate objectives of literature review, crack surveys, assessment of design factors, preliminary assessment of cost effectiveness, and findings support the main objective above.

- Literature review found information relevant to thermal cracking and utilizing the precut technique in pavements and applied that information to this study.
- Crack surveys were the method of data collection. Information was gathered before and after construction at the Moose Creek project and after construction at the

Healy project so that the locations of precuts could be compared to the locations of naturally occurring transverse cracks.

- Assessment of design factors (precut depth, spacing, and pavement structure) was completed by comparing test sections with specific attributes to control sections that did not contain precuts to determine if the design factors contribute to varying crack performance.
- Preliminary assessment of cost effectiveness was derived using very limited information to determine if precutting is viable.
- Findings were summarized and recommendations made.

1.3 Research Approaches

The objectives of this study were met using the following elements:

- Literature review
- Experimental precut sections in two construction projects
- Field survey and data collection
- Presentation of data and analysis
- Economic analysis of precut versus maintenance
- Conclusions and recommendations

1.3.1 Literature Review

The literature review in Chapter 2 describes what thermal cracks are and the current techniques used to prevent or maintain them. One method of preventing natural transverse thermal cracking is the precut technique. The review focuses on the application of the precut technique in pavement for both cement and asphalt. More emphasis is placed on research of the precut technique in asphalt and specific studies from multiple cold region states are included as well as information from Alaska.

1.3.2 Experimental Precut Sections in Two Construction Projects

Chapter 3 discusses two experimental sections. The first experimental section is "Richardson Hwy MP 340-346 Resurfacing (Moose Creek), Project #63362" which will be referred to as "Moose Creek" for this study. Moose Creek is approximately 16.5 miles Southeast of Fairbanks. The second experimental section is "Parks Highway MP 239-252 Rehabilitation, Project #61275" which will be referred to as "Healy" for this study. The Healy project is approximately 100 miles Southwest of Fairbanks, see Figure 1.1.

The Moose Creek project was constructed in 2012 with 9 test sections with precuts varying in depth and spacing and 1 control section. The Moose Creek project included a crack survey prior to removal of the existing road for comparison of preexisting cracks with future precut and natural cracks. The Healy Project was constructed in 2013 and includes 12 test sections with precuts varying in depth and spacing and 4 control sections. The Healy project also includes different pavement structures that vary from simple mill-and-pave to full reconstruction.

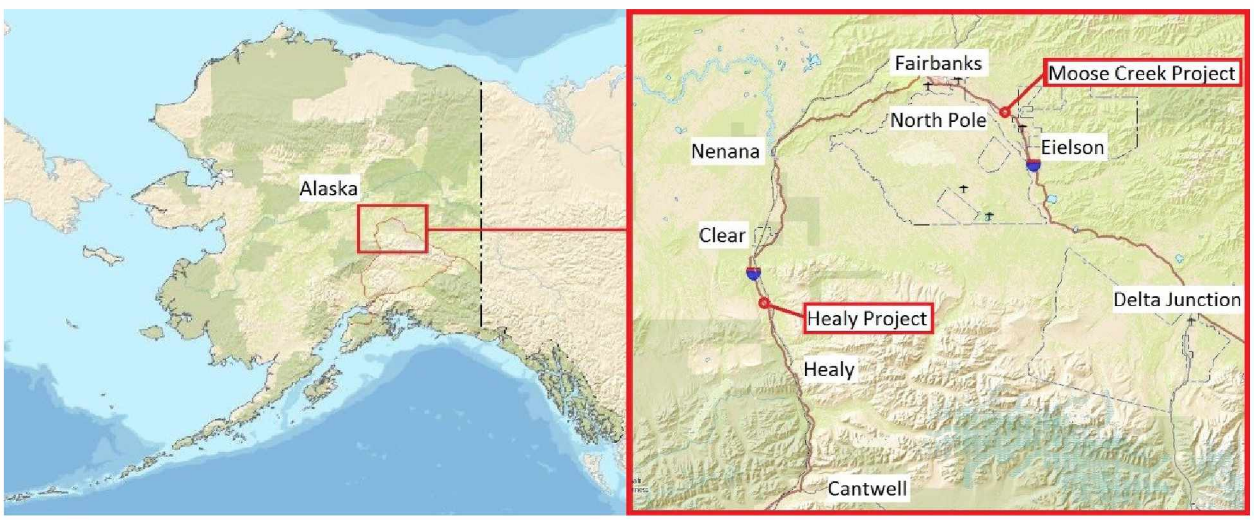

Figure 1.1 Project location map (Source: USGS, The National Map)

1.3.3 Field Survey and Data Collection

Chapter 3 describes how each research project was set up and the method for which data was collected in the field at both projects. Each project, similarly, used the same field log sheets to document the precuts that were installed and any new natural cracks that have developed during field surveys.

1.3.4 Presentation of Data and Analysis

Chapter 4 presents data and analysis. This study will place the data from both projects together in a format from which comparisons can be derived. Raw data can be found in the appendices on the field log sheets; Supplemental File A: Moose Creek crack survey raw data contains the field log sheets for Moose Creek and Supplemental File B: Healy crack survey raw data contains the field log sheets for Healy. The raw data is of paramount importance for the goals of this research as it contains the locations and conditions of all the post-construction cracks, precut and natural, which can be compared against the locations of the precuts installed during construction.

Precuts at Moose Creek and in Healy will be measured and quantified during site visits to gather data that can be analyzed. This data will be used to compare how the test road sections are performing in regards to thermal cracking, if new cracks are developing, and if the precuts are performing satisfactorily. By recording the locations and conditions of precut and new natural cracks, road sections will be analyzed side by side and correlations drawn. Costs to perform the precut work will be compared to costs associated with conducting crack repairs in a life-cycle economic analysis to determine if this technique will potentially save money on future projects.

Crack depth and spacing will be compared in each individual project as well as for both projects as a whole. Metrics for success are presented and applied to the precut sections and compared against each other. Generalizations for the best performing precut techniques are covered in this section.

The length between natural cracks will be used as a measure to determine the effectiveness of the precut technique in all test and control sections and comparisons will be concluded from the data collected at Moose Creek and Healy. The success rates for Moose Creek and Healy will be compared to each other as well as with the 50 test sections that were a part of the Minnesota Department of Transportation Report Number 96-27 (Janisch and Turgeon 1996).

1.3.5 Economic Analysis of Precut Versus Maintenance

Chapter 5 discusses the basis for costs associated with the precut technique and its alternative, regular crack maintenance. With the scope of this study, costs for the precut technique are discussed, compared, and generalized for the purpose of conducting a cost effective analysis of the technique. The initial installation and minor natural crack maintenance costs for the precut technique are weighed against the costs of maintaining natural cracks in the road by predicting the total future cost of each alternative in present day dollars using a discount interest rate. Only very preliminary conclusions can be drawn from the limited amount of cost data available currently.

A second analysis is completed in chapter 5 to determine if the current experimental sections are on track to be cost effective at this time. Using a linear interpolation of the number of natural cracks required to form in the control sections versus the precut sections per year, conclusions are drawn as to whether the actual natural cracking is enough to consider the experiment cost effective on a section by section basis.

1.3.6 Conclusions and Recommendations

Chapter 6 discusses an overview of what this study has accomplished in terms of the success, optimal precut section parameters, and the economic feasibility of utilizing the precut technique. The findings from this study can be used as a starting point for future studies and construction of new sections utilizing the precut technique. In addition, recommendations are made to help identify needs for future research on applying the precut technique to minimize transverse thermal cracking in asphalt concrete pavements.

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Chapter 2 Literature Review

2.1 Thermal Cracks in Asphalt Pavements

Thermal cracks form in asphalt pavement when the internal tensile stress in the asphalt concrete layer exceeds its tensile strength. Due to this thermal contraction of the pavement, a crack initiates at the surface of the road where the temperature is the coolest and propagates downward to the bottom of the asphalt bound layer. This happens when the ambient temperature of the air decreases to a level lower than the temperature of the asphalt concrete causing the top of the asphalt layer to cool down more rapidly and begin contracting earlier than the bottom. Once an initial crack develops, a stress relief point is established and the crack can propagate and fully form as the rest of the asphalt layer cools and contracts. Thermal cracks, which are transverse cracks perpendicular to traffic, are different than fatigue cracks. Fatigue cracking is due to the repeated application of tensile strains at the bottom of the asphalt layer. Fatigue cracks propagate from the bottom of the layer due to repeated vehicular traffic.

Thermal cracking can also occur from diurnal temperatures which apply a constant cyclical stress leading to thermal fatigue cracking. Thermal fatigue cracking is different from major, or just normal thermal cracking, because it is caused by repetitive temperature-induced stress loadings versus one large temperature decrease. Many factors can contribute to thermal cracking including temperature, rate of temperature change, coefficient of thermal contraction, pavement slab geometry, constraint, aging, stiffness, fracture toughness, fracture energy, polymer additives, reclaimed asphalt content, air voids, and mixture aggregate.

Thermal cracking has been studied extensively in Alaska and the following reports provide much more in depth knowledge on the subject: (McHattie 1980), (Osterkamp et al. 1986), (Raad et al. 1995), and (Zubeck and Vinson 1996).

Although ADOT&PF still uses the performance grade system for classifying asphalt cement, new tests have been developed that could help determine how well a certain asphalt could resist cracking in the colder temperature climates. One such test is the new Asphalt Binder Cracking Device Test (Kim 2013).

2.2 Maintenance Approaches for Thermal Cracking

Thermal cracking can either be prevented using a proactive approach, or repaired after occurring in a more reactive manner. Different methods of reducing or maintaining thermal cracking are described below. The most widely used method is crack sealing, while other methods include better mix designs, use of asphalts containing beneficial materials properties, and precutting.

Currently one of the most prevalent maintenance activities for pavements is crack or joint sealing. Departments, government agencies, and private industry regularly utilize joint sealing maintenance for both rigid and flexible pavements. Joint sealing began early in the development of concrete pavement in the 1920s (Morian and Stoffels 1998). Morian and Stoffels pointed out that sealing joints accomplishes two purposes, to prevent water from infiltrating the pavement structure and to minimize the amount of incompressible materials (other than water) entering the joint or reservoir (1998). They conducted an experiment to compare multiple joint seal technologies against each other along with not sealing joints at all in his paper titled: Joint Seal Practices in the United States, Observations and Considerations. The paper concluded that joints need to be investigated on a local level to determine maximum and minimum temperature regimes, site-specific material information, and pavement designs that will work with certain joint sealing techniques. Most excitingly, the paper concluded that leaving cracks unsealed may be the most cost effective means of dealing with the pavement distress in locations where the joints are thermally locked during a great portion of the year (expanded during the summer) or where coarse-graded subgrades exist that can drain water. This conclusion is similar to one from an evaluation of transverse thermal cracks in Alaska where the author claims that many of the thermal cracks not in a bad condition may remain unsealed (McHattie et al. 2013). Lastly, one of the greatest considerations in joint sealing is the quality of construction. Careful care and quality assurance is of paramount importance, sometimes even more so than the crack sealant design or material choice, because installing a sealed joint incorrectly does not actually effectively seal the joint and will fail immediately.

Another approach to minimize the impacts of thermal cracking is the use of better mix designs for asphalt concrete. Changing the asphalt content, void ratio, or aggregate gradation has the potential to affect the final pavement structure's natural crack frequency. In Iowa, a research project investigated if changing the asphalt content of the asphalt treated base (ATB) section of the road would have any impact on transverse cracking (Marks 1984). The study titled "Reducing the Adverse Effects of Transverse Cracking" discovered that by just increasing the asphalt content of the ATB layer by 1%, natural cracks occurred every 528 feet instead of every 170 feet. Increasing the asphalt content by 1% reduced the void space in the ATB layer from 11.1% to 6.7% which is also thought to have helped reduce the occurrence of transverse cracking in the research project.

The Iowa study also included another means of reducing the number of transverse cracks; using different asphalts in separate test sections (Marks 1984). The performance grade system of asphalt classification used today replaced older systems including the one that the Iowa project utilized which included the penetration-viscosity (pen-vis) number, a method of describing asphalt grade. Using the pen-vis system, asphalts from two separate source locations were used in different test sections. The test section with a higher pen-vis number meant that the asphalt had low temperature susceptibility, and the test section with the lower pen-vis number had high temperature susceptibility. The research data showed that the low temperature susceptible asphalt exhibited natural crack spacing of 170 feet while the high temperature susceptible asphalt exhibited natural crack spacing of only 35 feet. This means that asphalt binder grade could have a tremendous impact on the occurrence of transverse cracking and that this method of reducing the number of transverse cracks warrants future studies. Lastly, the precut technique can be used to reduce future transverse thermal cracking. The precut technique is described in section 2.3.

2.3 Application of Precut Technique in Pavement

The idea of precutting pavements has been around for a long time in rigid pavements like concrete, but is a relatively new method to control thermal cracking in asphalt pavements. Precutting works by sawing a slot into recently hardened concrete or asphalt pavement perpendicular to the centerline of the road. These slots provide a stress concentration point for the slab of pavement, and as the pavement cools and contracts the stress points continue to crack through the entire pavement layer releasing the stress. Procedures, depth and timing of the precuts have been studied to help improve performance of precuts (Gaedicke et al. 2007). For concrete pavement, initiating a stress relief point with a precut may dictate where natural cracks will occur during cooling after curing, drying shrinkage, and diurnal or seasonal temperature changes. For asphalt pavement, precuts will help choose locations for the pavement layer, slab, to crack during diurnal and seasonal temperature changes. By controlling the location of where cracks will develop, newly constructed roads with precuts could maintain a better, more professional looking appearance. Precuts could potentially also provide the road user with a more pleasant and smooth ride by reducing the spalling and settlement that occurs in natural transverse thermal cracks.

The precut technique researched in this study attempts to mimic the interval spacing of natural transverse thermal cracking by placing precuts at distances similar to those that occur randomly in the field. Natural crack spacing is a topic in asphalt pavements that needs more research, modelling, and empirical evidence to pin down, but some research has touched on the surface of determining the optimal crack spacing.

2.3.1 Precuts in Concrete Pavement

The precut application has been widely used in rigid pavements. Portland cement concrete (PCC) is not flexible like asphalt concrete, and is sure to crack when exposed to differing thermal conditions leading to expansion and contraction of the material due to temperature changes in weather, temperature gradients from heating and cooling, and initial thermal cooling from construction. To battle the issues of cracking, different methods have been employed for multiple types of concrete to eliminate the occurrence of natural cracking, reduce the number of natural cracks, or allow natural cracking to take place in a controlled fashion. The different methods for controlling cracking in Portland cement concretes includes placing more reinforcement into the concrete, saw cutting after the slab has been placed using early-entry sawing or conventional sawing, or pouring in cold or construction joints during construction.

Research is still being performed in the concrete road field because there are so many variables that lead to the failure of concrete and one issue that specifically relates to utilizing the precut technology is the failure mechanism of transverse cracking. Traditionally, continuously reinforced concrete pavements (CRCP) have been allowed to crack naturally but this natural cracking prematurely leads to pavement distresses such as punchouts and spalling (Kohler and Roesler 2004). Erwin Kohler and Jeffrey Roesler from the University of Illinois conducted an experiment using ten test sections in a laboratory that utilized two different crack controlling methods, early entry sawing and tape insertion (2004). The early entry sawing was conducted four hours after the concrete was placed and the tape insertion occurred in a similar time frame. The early entry sawing, similar to the experiments in this paper, was cut to a 1.5 inch depth while the plastic tape was set 3 inches into the fresh concrete. Both were set at 2, 4, and 6 foot spacing in the concrete. The experiment concluded that both sawing and tape insertion methods produced cracks that were straighter, developed sooner, and existed in regular intervals as opposed to clusters or y-shaped formations. This promising experiment showed that cracks could be controlled, or engineered, to perform better in a road surface made of Portland cement concrete, and the ideas for this study's experiment follows the same line of thinking.

Another experiment on early-entry sawing was conducted, not to compare the success of sawing versus not sawing, but to determine if the early-entry sawing caused durability issues in the concrete road. James M. Krstulovich et al. conducted the experiment titled: Evaluation of Potential Long-Term Durability of Joints Cut With Early-Entry Saws on Rigid Pavements (2011). The study points out that conventional sawing that typically occurs 4 to 12 hours after concrete pavement runs into issues including early cracking from base or subgrade restraint, cement drying shrinkage, temperature and moisture differential between concrete and underlying subbase, daytime-nighttime curling, and random cracking from late sawing or inadequate saw depth. The early entry sawing technique was tested to see if any or all of the issues involved in conventional sawing could be eliminated. The early-entry sawing, usually performed 1 to 4 hours after slab placement, utilized shallow cuts because the timing allowed for the addition of the stress reliefs, cracks, before any significant tensile stresses developed. The study placed a test section along a 1,000 foot section of Illinois route 59 in Plainfield. The project concluded that early-entry sawing induced cracks beneath almost all of the precut locations, joint condition remained the same for one year, no extra micro cracking occurred near the precuts, multiple freeze-thaw cycles yielded no deterioration, salt had little to no adverse effect on the cracks, and only slight raveling occurred near some of the cracks. Overall, the project determined that early-entry sawing is a viable option for preventative crack maintenance on Portland cement concrete. This experiment is promising because it looks at determining how well the early-entry sawing method works and not just if the method works.

Another research project undertaking occurred in Missouri where three projects included the early-entry sawing method to control random transverse cracking (Chojnacki 2001). In this research, test sections that were conventionally sawed to a 3 inch depth were compared to early entry saw sections cut to depths of 1.5, 1.75, and 2.25 inches. All test sections were reported to have performed satisfactorily but it was noted that the deeper early entry saw cuts induced natural cracking sooner than the more shallow ones. Similar research will need to be conducted on asphalt cement pavement after the determination is made if the precut technique is effective in controlling cracking.

2.3.2 Precuts in Asphalt Pavement

The effectiveness of the precut technique in asphalt concrete pavements has been examined in a few of the northern states including Alaska, Connecticut, Iowa, Maine, Massachusetts, Minnesota, New York, North Dakota, and Pennsylvania. Some of the very first research projects were conducted in Minnesota (Morchinek 1974) and Iowa (Marks 1984). Alaska has experimented on an over 30 year old section of road in Fairbanks and on the two test sections examined in this study as well as at the Fairbanks international Airport. Minnesota developed one of the most extensive research projects comparing 50 sections of precuts where the saw and seal method was utilized in 1996 (Janisch and Turgeon 1996). Maine completed a comparison of the saw and seal technique to the use of different performance grade asphalts in 2004 (Marquis 2004a). North Dakota Materials and Research division evaluated one project that included many test sections evaluating the success of sawing and sealing in bituminous pavements in 2007 (Evert and Richter 2007).

2.3.2.1 Iowa Research

Vernon J. Marks with the Iowa Department of Transportation investigated 8 test sections to determine three separate conclusions (Marks 1984). The first two, determining if asphalt grade and asphalt content could reduce thermal cracking have been discussed in Section 2.2. The third was investigating precut spacing. The project placed precuts at intervals of 40, 60, 80, and 100 feet and sealed them. Each precut was 1/4 inch wide by 3 inches deep. The pavement structure was 3 inches of asphalt surface course over 8 inches of asphalt treated base. After 3.5 years all of the seals had failed, but no detrimental effects had occurred at the precut locations, which may indicate that sealing cracks is not necessary for precuts. Not a single natural crack was recorded in the first 3.5 years, which the authors said was not a surprise considering the control section natural crack interval was 170 feet. This means the precuts were effective in preventing natural transverse cracks from forming.

2.3.2.2 Minnesota Research

Minnesota conducted one of the first studies on the precut technique as part of Special Report No. 315, “Sawing Joints to Control Cracking in Flexible Pavements” (Morchinek 1974). The research from Special Study No. 315 was similar to a much more extensive research project on the sawing and sealing technique in report Number 96-27 “Sawing and Sealing Joints in Bituminous Pavements to Control Cracking” produced by the Minnesota Department of Transportation in March 1996 (Janisch and Turgeon 1996). This project evaluated over 50 sections of road including new hot mix asphalt construction, bituminous overlays on concrete, and bituminous overlays on bituminous pavements. “Sawing and sealing” is the method of utilizing a precut that is also filled with asphaltic binder material immediately after construction. The experiment points out that on new construction, the stress point on the bituminous pavement is at the top where thermal stresses contract and expand the pavement the most. By adding a precut, the idea was to introduce a weakened stress point where a crack would form instead of at a random location. On areas where bituminous overlays were used, the stress locations were not only at the top of the pavement for thermal stress, but also at the bottom of the bituminous layer where an existing crack was present below. In instances where a crack was existing in the layer beneath where paving occurred, horizontal and or vertical movement of the slab below added a stress point at the bottom of the new bituminous layer, this phenomenon leads to the formation of reflective cracks.

The success of the saw and seal method was determined by dividing the number of precuts by the number of precut and natural forming cracks added together. For instance, a section that had 4 precuts and no natural cracks would have a success rate of 100% while a section with 4 precuts and 3 natural cracks would have a success rate of 57%. The study found that approximately three quarters of the test sections were successful after 5 years with success being defined as a success rating of 75% or greater. The greatest discoveries found that the saw and seal method worked well for most new pavement construction and worked on bituminous overlays of concrete when the cuts were aligned with the concrete joints. The study found that bituminous overlays of bituminous materials sections were not very effective, except for the one section where precuts were aligned over existing cracks that were straight, this section performed exceptionally well. Lastly, the bituminous overlays of concrete that had many mid-pane cracks and badly deteriorated joints did not perform very well. Unlike the research performed for this paper, the Minnesota experiment sealed all of the precuts by including a reservoir area in the precut for backer rods and sealant to be poured

The Minnesota experiment showed promising results and gave recommendations for where to use the technique and what to avoid. The new bituminous pavements also evaluated the effect of precut spacing and it was determined that cracks cut between 30-50 feet would control thermal and random cracking while cuts spaced at 60 feet would not. Saw cut depth was also evaluated but no conclusive evidence was determined for new bituminous pavements and only a suggestion of cutting at least one third of the pavement depth was made. Bituminous pavements on concrete should be cut to a depth of 2 inches or one third the pavement thickness, whichever is greater. Lastly, bituminous overlays of bituminous pavement should be cut very deeply, at least one third of the pavement depth, or the underlying cracks may meander away from the new precut location.

2.3.2.3 Maine Research

Another project conducted in the northern state of Maine was Technical report 96-25 and 97-19 “Experimental Use of Sawed and Sealed Joints to Minimize Thermal Cracking,” (Marquis 2004b). The Maine experiments tested two sections, the Beddington and Sherman projects. Both projects utilized a saw cut that was 1/8 inch wide by 2.5 inches thick with a reservoir centered at the top that was 1/2 inch wide by 5/8 inches deep and filled with asphalt sealant. The Beddington project required bond breaker tape and hot lance cleaning whereas the Sherman project did not. The first project, Beddington, included a new section of 9.5 inch thick hot mix asphalt. The Beddington test section had no natural transverse cracks in the test or control sections. The second project, Sherman, included 8 inches of reclaimed asphalt repaved with 4.5 inches of hot mix asphalt. No natural transverse cracks developed in the Sherman project test sections, but did develop in the control section of this experiment. Both projects did not precut on the shoulders, and it was mentioned that cracks did form out of the ends of the precuts through the shoulders, so using the precut technique across the full with of the pavement is preferred. The authors also mentioned that some of the precut sealants failed due to not including bond breaker tape on the Sherman project.

2.3.2.4 North Dakota Research

The North Dakota DOT Materials and Research Division conducted an experimental study ND 98-05 “Sawing and Sealing Joints in Bituminous Pavement to Control Cracking” (Evert and Richter 2007). This study included five test sections with different joint spacing and sealant reservoir dimensions and one control section with no joints. The study measured the success of the jointed sections using an equation similar to the Minnesota Report 96-27 where the success equaled the number of sawn joints divided by the combined number of sawn joints and natural cracks between joints. This project strived for a success rate of 85% unlike the 75% criteria used in the Minnesota research (Janisch and Turgeon 1996). A second criteria was used because sealant failure could be an issue, so if the sealant losses adhesion or tears it was also considered a failure on a single joint basis. The project used the “mine and blend” technique which is similar to the “mill and fill” technique AKDOT uses to create crushed asphalt base course. A layer of 11.5 inches of base was topped with 5 inches of hot bituminous pavement with asphalt binder PG 52-28, the same binder used in most Alaskan projects.

The saw cuts were 1/8 inch wide and extended all the way through the bottom of the bituminous layer. Three different reservoirs were cut into the upper section of each saw cut and filled with backer tape and sealant. Three joint spacing intervals of 30, 40, and 80 feet were tested.

After 4 years of monitoring, few new transverse cracks developed in the test sections of this project, the success rates ranged from 89% to 100%. The test section with 89% success had a crack spacing of 80 feet. Many sealants failed due to adhesion after four years, which may not be bad in terms of the research for this paper. If the sealants failed and are open to the environment during the winter when the pavement contracts and is open and few new transverse cracks have formed in the test section, this could suggest the cracks do not need to be sealed like in the Moose Creek and Healy experimental sections in Alaska.

2.3.2.5 Alaska Research

Alaska has a few test sections in the roads near Fairbanks and also at the Fairbanks International Airport (Griffith 2011). One test section in Fairbanks is over 30 years old, constructed October, 1984, and is located on Phillips Field Road. Phillips Field Road is a heavily trafficked area providing access to many industrial businesses near the center of Fairbanks. Although most of Phillips Field Road was recently repaved, one small section remains near Peger Road where precuts were sawed close to completely through the pavement during construction at a 50 foot spacing interval. The precuts on Phillips Field Road still remain in a very satisfactory condition with minimal spalling and little to no settlement. Unfortunately, no study or continuous monitoring was conducted on Phillips Field Road for the long term, but the test section that remains provides excellent positive reinforcement to the ideas tested on the two new projects investigated in this study. This section is a promising look at the longevity and potential success of the precut technique.

The Fairbanks International Airport included the saw and seal technique recently in the "Fairbanks International Airport FIA Apron Improvements" project constructed in 2013 (Griffith 2011). A grid of precuts was installed to alleviate thermal cracking in the massive airport tarmac. This grid also helps channel water off of the tarmac while avoiding potentially dangerous sheet flow that could lead to hydroplaning. These cracks have not been evaluated for success, but were installed with a similar design that other airports in the contiguous United States have used, which is also similar to the Minnesota and Maine research projects.

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Chapter 3 Field Work

3.1 Description of Field Projects

3.1.1 Moose Creek

The Moose Creek experimental site was constructed in 2013 as part of the "Richardson Hwy MP 340-346 Resurfacing (Moose Creek), Project #63362." The experimental cuts were made at various spacing (25 feet, 40 feet, and special spacing) and to 3 different depths (0.5, 1.0, and 1.5 inches). The asphalt concrete layer thickness was 2 inches as shown in Table 3.1. Precut work was performed by an employee of Great Northwest, Inc., the construction project's main contractor, on the southbound lanes. During cutting, traffic control consisted of closing a single lane of the two south bound lanes. The single lane closure allowed cutting of approximately two thirds of the 2-lane width from one side of the road. After all cuts were partially completed, the lane closure was switched to the adjoining lane to allow completion of the saw cuts. The cuts extended from edge of pavement to edge of pavement (full two-lane width, including shoulders) at each cut location. Saw cutting of the 111 full-width slots required three full workdays. Weather during the sawing operation ranged from partly cloudy to rain, with temperatures between 50 and 80 degrees Fahrenheit.

The equipment used was a Saw Devil walk-behind saw machine with a 12 inch diamond saw blade (1/8 inch thick) and a flatbed truck with a 300 gallon tank of water for cooling the saw blade. The time required to layout and cut the first two thirds of each line was approximately 12 minutes, or about 15 minutes total per line plus time required to move the cutting operation from one lane to the other. This time was averaged over several of the different depths of cuts. Figure 3.1 shows the saw equipment as well as the type of thin diamond saw used at Moose Creek.

Figure 3.1 Saw Devil equipment and operator (left) and thin diamond saw blade used (right)

The Moose Creek experimental site consisted of ten sections, including the critical control section. The total length of the experimental section was 1.2 miles, between Station 989+95 (MP 343.8, 64°43'08" N Lat., 147°13'01" W Long) and Station 1043+38 (MP 342.6, 64°42'49" N Lat., 147°11'06" W Long). No saw cutting was done within the control section, saw cutting was done in the other nine sections. For sections receiving precuts, the cuts were made to various depths and spacing indicated in the following list:

- Section 1: Sta. 989+95 to 1003+15. Control Section without saw cuts; Section Length (L) = 1,320 feet.
- Section 2: Sta. 1003+15 to 1006+92. 17 cuts of 0.5" depth 25' apart; L=377 feet.
- Section 3: Sta. 1007+17 to 1011+57. 17 cuts of 1.0" depth 25' apart; L=440 feet.
- Section 4: Sta. 1011+97 to 1015+97. 17 cuts of 1.5" depth 25' apart; L=400 feet.
- Section 5: Sta. 1016+37 to 1020+37. 11 cuts of 0.5" depth 40' apart; L=400 feet.
- Section 6: Sta. 1020+77 to 1024+77. 11 cuts of 1.0" depth 40' apart; L=400 feet.
- Section 7: Sta. 1025+17 to 1029+17. 11 cuts of 1.5" depth 40' apart; L=400 feet.
- Section 8: Sta. 1030+60 to 1034+52. 7 cuts of 0.5" depth with cuts located over the cracks in the asphalt that was replaced (the preconstruction natural thermal cracks). L=392 feet.
- Section 9: Sta. 1035+11 to 1038+96. 10 cuts of 1.0" depth with cuts located over the cracks in the asphalt that was replaced (the preconstruction natural thermal cracks). L=385 feet.

- Section 10: Sta. 1039+19 to 1043+39. cuts of 1.5" depth with cuts located over the cracks in the asphalt that was replaced (the preconstruction natural thermal cracks). L=420 feet.

All ten sections were built using the same pavement structure (Pavement Structure I in Table 3.1) which included a 2.0 inch thick layer of asphalt concrete over crushed asphalt base course material. Table 3.1 and the Appendix include pavement structure details. Precuts were installed the full width of 38 foot from edge of shoulder to edge of shoulder going southbound. There are two 12 foot lanes with a 4 foot shoulder on the inside and 10 foot shoulder on the outside. Annual average daily traffic for the inside lane was 936 on the inside lane and 2,806 on the outside lane. Weather data from the Fort Wainwright Ladd Army Airfield (15 miles Northwest of the experimental site location) recorded -47 degrees Fahrenheit as the minimum temperature for both the 2013-2014 and 2014-2015 winters, the maximum temperatures were 93, 86, and 87 for 2013, 2014, and 2015 respectively. The 2013-2014 winter recorded 4,544 freezing degree days and the 2014-2015 winter recorded 4,329 freezing degree days.

3.1.2 Healy

The Healy test sections were first introduced when UAF and ADOT&PF teamed up to create and implement the "Work Plan for Special Design Features & Crack Sealing Maintenance for IM-OA4-4(15) Parks Highway M.P. 239-252 Rehabilitation" (Liu and McHattie 2013). This work plan laid out the need for such research and the steps to implement research and data collection to accomplish the desired results, which parallel this thesis. The work plan originally called to locate and record the location of all existing transverse cracks before demolishing the pavement, precut new slots into the roadway after construction, and continue monitoring those precuts. Unfortunately, the existing transverse cracks were not recorded before the demolition of the existing pavement, but the construction and monitoring of the experimental sites did occur as part of that work plan and this thesis.

Precuts were installed in Healy during the summer of 2014 as part of "Parks Highway MP 239-252 Rehabilitation, Project #61275". Quality Asphalt Paving, the contractor, used a surveyor equipped with a GPS receiver to locate and mark the location of each precut by using designated stationing and crack separation distances. Precuts were marked on the asphalt with spray paint using the rabbit-track technique (Figure 3.2) where short dashes were sprayed across the full width of the road. The crack layout process took approximately one full day with all six individuals working; one surveyor, three laborers, and two flaggers.

Figure 3.2 Surveyors laying out precuts with rabbit-tracks

The precut sawing process required one laborer to operate the saw, two traffic control flaggers, and one water truck driver periodically. The saw operator would start on one side of the road at the edge of shoulder and begin to saw cut towards the other. Traffic would be routed through one-way by the flaggers until the saw reached the centerline. Once the saw was in the opposite lane, traffic would be shut down until the remainder of the road was cut. Saw cutting of the 318 full-width slots required approximately seven full workdays. Weather during the sawing operation ranged from partly cloudy to rain and snow, with temperatures between 30 and 60 degrees F.

The precuts were sawed into the pavement using a walk-behind saw machine similar to that of the “Saw Devil” brand with a 12-inch diamond tooth blade 1/8-inch wide (Figure 3.3). Other equipment included one pickup truck with a water tank and equipment lift and one water truck to refill the water tank. ADOT&PF used a ruler during construction inspections to ensure compliance with the precut plan, (Figure 3.4).

Figure 3.3 Precut cutting equipment

Figure 3.4 Inspection of crack depth (left) and crack width (right)

The Healy experiment consisted of 16 sections, including 4 control sections. Sections are numbered in sequential order starting at section 11 for comparison with Moose Creek sections.

No saw cutting was done within the control sections. The total length of the experimental section was 6.7 miles, between Station 4585+00 (MP 251.9, 63°54’34” N Lat., 149°4’35” W Long) and Station 4941+75 (MP 245.2, 63°49’23” N Lat., 148°59’24” W Long). The cuts were made to various depths, spacing, and pavement structure (PS) indicated in the following list:

- Section 11: Sta. 4585+00 to 4590+50. 23 cuts of 2.0” depth 25’ apart PS II; L=550 feet.
- Section 12: Sta. 4590+50 to 4596+20. Control Section without saw cuts PS II; L=570 feet.
- Section 13: Sta. 4596+20 to 4601+80. 17 cuts of 2.0” depth 35’ apart PS II; L=560 feet.
- Section 14: Sta. 4603+00 to 4610+00. 29 cuts of 2.0” depth 25’ apart PS III; L=700 feet.
- Section 15: Sta. 4610+00 to 4617+00. Control Section without saw cuts PS III; L=700 feet.
- Section 16: Sta. 4617+00 to 4624+00. 21 cuts of 2.0” depth 35’ apart PS III; L=700 feet.
- Section 17: Sta. 4858+00 to 4865+75. 32 cuts of 0.625” depth 25’ apart PS IV; L=775 feet.
- Section 18: Sta. 4866+00 to 4873+75. 32 cuts of 1.25” depth 25’ apart PS IV; L=775 feet.
- Section 19: Sta. 4874+00 to 4881+75. 32 cuts of 2.0” depth 25’ apart PS IV; L=775 feet.
- Section 20: Sta. 4881+75 to 4890+00. Control Section without saw cuts PS IV; L=825 feet.
- Section 21: Sta. 4890+00 to 4897+70. 23 cuts of 0.625” depth 35’ apart PS IV; L=770 feet.
- Section 22: Sta. 4898+05 to 4905+75. 23 cuts of 1.25” depth 35’ apart PS IV; L=770 feet.
- Section 23: Sta. 4906+10 to 4913+80. 23 cuts of 2.0” depth 35’ apart PS IV; L=770 feet.
- Section 24: Sta. 4915+00 to 4924+00. 37 cuts of 2.0” depth 25’ apart PS V; L=900 feet.
- Section 25: Sta. 4924+00 to 4933+00. Control Section without saw cuts PS V; L=900 feet.
- Section 26: Sta. 4933+00 to 4941+75. 26 cuts of 2.0” depth 35’ apart PS V; L=875 feet.

Precut sections were situated on four different pavement structures at the Healy project, structures II-V. The pavement structure characteristics from top of the road surface down can be seen in Table 3.1 and in the Appendix. All precuts were installed the full width of pavement from edge of shoulder to edge of shoulder going southbound. Sections 11-17, 25, and 26 were 48 foot wide including three 12 foot lanes, one each direction with an additional passing lane in the Northbound direction, and a 4 foot shoulder on the Northbound lane and 8 foot shoulder on the Southbound lane. All other sections were on two 12 foot lanes with two 8 foot shoulders. Annual average daily traffic for each lane was 1,150; it is unknown how 1,150 was distributed when there was a passing lane present. Weather data from the Nenana Municipal Airport (35 miles north of the experimental site location) recorded -43 degrees Fahrenheit as the minimum temperature for both the 2014-2015 winter; the maximum temperatures were 84 and 91 for 2014, and 2015 respectively. The 2014-2015 winter recorded only 1,272 freezing degree days during the unusually warm winter.

Table 3.1 Pavement structures

Pavement Structure	I	II	III	IV	V
Layer 1	2.0" Asphalt Concrete; Type II, Class B. PG 52-28	2.5" Asphalt Concrete; Type II, Class B. PG 52-28	2.5" Asphalt Concrete; Type II, Class B. PG 52-28	2.5" Asphalt Concrete; Type II, Class B. PG 52-28	2.5" Asphalt Concrete; Type II, Class B. PG 52-28
Layer 2	Crushed Asphalt Base Course	3" Asphalt Treated Base	3" Asphalt Treated Base	3" Asphalt Treated Base	3" Asphalt Treated Base
Layer 3		34" Selected Material, Type A	4" Minimum Crushed Asphalt Base Course	16" Selected Material, Type A	26" Selected Material, Type A
Layer 4		Geotextile Reinforcement, Type I		22" Selected Material, Type B	Geotextile Reinforcement, Type I
Layer 5		8" Selected Material, Type A			8" Selected Material, Type A
Layer 6		Geotextile Reinforcement, Type I			Geotextile Reinforcement, Type I
Layer 7					8" Selected Material, Type A
Layer 8					Geotextile Reinforcement, Type I

Table 3.1 describes each of the five pavement structures and its layers. Materials were in conformance with the 2004 Standard Specifications for Highway Construction, Alaska Department of Transportation & Public Facilities “Blue Book” (ADOT&PF, 2004).

Pavements structure V is the strongest, most sound structure for the road followed by II, IV, III and I. Pavement structures I and III utilize the mill and fill technique where the older pavement is reclaimed, creating crushed asphalt base course, and then shaped and compacted followed by paving.

3.2 Field Survey and Data Collection

3.2.1 Moose Creek

Crack surveys (Figure 3.5) were performed on 10/22/2013 and 4/24/2014. The crack surveys required measuring the distance of every visible major transverse thermal crack from the starting point at Station 989+95. These measurements were done using a surveyor’s “walking wheel,” with a precision of about ± 2 foot over the mile-long experimental section.

These crack location determinations were made while walking in the right shoulder of the southbound lanes. Most of the transverse cracks were found to be skewed to the roadway centerline. Therefore, the location of each transverse crack was noted on the field data sheet as the location of the right end of the crack.

The locations of all precuts were also determined as part of the 2013 and 2014 surveys. This was done, in part, for the purpose of making sure that the walking wheel was giving accurate locations over the entire survey mile. All precuts were found to be at the locations listed by AKDOT&PF engineers after construction. Using the measuring wheel, they were found to be within 2 feet or less of the listed locations throughout the entire mile. Precuts were all perpendicular to the road with no skew.

Raw data obtained during the research project is contained in Supplemental File A: Moose Creek crack survey raw data. Items of raw data pertinent to the experimental section include crack survey data obtained on 10-22-2013 and 4-24-2014.

It is important to note the distinction between the precuts and natural cracks discussed later. As used here, the term “natural crack” refers to those transverse cracks that extend across the full width of the paved surface and are not precut. Precuts that have already (or will) become active are of course involved in the natural cracking process, but they are not considered natural cracks per se. Precuts, whether active or not, are a pavement design feature and not a form of damage. Limited evidence so far in Alaska suggests that precut transverse cracks may need no maintenance sealing or filling for the life of the pavement. Therefore, the purpose of this analysis is to determine the extent to which various precut designs are able to limit, i.e., control development of natural thermal cracking not associated with the precuts.

The frequency of natural transverse cracks observed during the 2013 and 2014 surveys at Moose Creek is tabulated in Table 3.2. The control section had the most cracks at 32 in 2013 which later increased to 39 in 2014. The test sections ranged from 3 to 9 natural cracks in any given test section for both years. It is important to note that none of the sections where the precut spacing varied, where cuts were placed over existing crack, the number of natural cracks remained the same from the first to the second year. All of the precuts and control sections for Moose Creek were on pavement structure I.

Figure 3.5 Field survey of Moose Creek, 2014 (left) natural transverse crack (right)

Table 3.2 Moose Creek (Richardson Highway) natural crack frequency

Year of Data Collection	Section	Precut Depth (in)	Precut Spacing (ft)	Pavement Structure	Section Length (ft)	Number of Precuts	Number of Natural Cracks
2013	1	Control		I	1320	0	32
	2	0.5	25	I	375	16	7
	3	1	25	I	440	18	3
	4	1.5	25	I	400	17	6
	5	0.5	40	I	400	11	5
	6	1	40	I	400	11	5
	7	1.5	40	I	400	11	4
	8	0.5	varies	I	392	7	6
	9	1	varies	I	385	10	4
	10	1.5	varies	I	420	10	4
2014	1	Control		I	1320	0	39
	2	0.5	25	I	375	16	9
	3	1	25	I	440	18	5
	4	1.5	25	I	400	17	7
	5	0.5	40	I	400	11	9
	6	1	40	I	400	11	6
	7	1.5	40	I	400	11	5
	8	0.5	varies	I	392	7	6
	9	1	varies	I	385	10	4
	10	1.5	varies	I	420	10	4

3.2.2 Healy

One crack survey has been performed at Healy on 5/22/2015 (Figure 3.6). The crack surveys required measuring the distance of every visible major transverse thermal crack from the starting point at Station 4585+00. These measurements were done using a surveyor's "walking wheel," with a precision of about ± 2 foot over the each experimental section. These crack location determinations were made while walking in the right shoulder of the southbound lanes and double checked walking back along the shoulder of the northbound lane. Most of the transverse cracks were found to be skewed to the roadway centerline. Therefore, the location of each transverse crack was noted on the field data sheet as the location of the center of the crack. The locations of all precuts were also determined as part of the 2015 survey. This was done, in part, for the purpose of making sure that the walking wheel was giving accurate locations over the entire section. Raw data obtained on field log sheets during the crack survey on 5/22/2015 is contained in Supplemental File B: Healy crack survey raw data. The frequency of natural transverse cracks observed during the 2015 survey is tabulated in Table 3.3.

Table 3.3 Healy natural crack frequency

Year of Data Collection	Section	Precut Depth (in)	Precut Spacing (ft)	Pavement Structure	Section Length (ft)	Number of Precuts	Number of Natural Cracks
2015	11	2	25	II	550	23	0
	12	Control		II	570	0	5
	13	2	35	II	560	17	0
	14	2	25	III	700	29	0
	15	Control		III	700	0	7
	16	2	35	III	700	21	2
	17	0.625	25	IV	775	32	0
	18	1.25	25	IV	775	32	2
	19	2	25	IV	775	32	1
	20	Control		IV	825	0	0
	21	0.625	35	IV	770	23	4
	22	1.25	35	IV	770	23	1
	23	2	35	IV	770	23	1
	24	2	25	V	900	37	0
	25	Control		V	900	0	2
	26	2	35	V	875	26	1

Figure 3.6 Natural transverse thermal crack at Healy (left), precut at Healy (right)

Chapter 4 Data Analysis

4.1 Criteria Used in Data Analysis

Two simple formulas were used to evaluate the effectiveness of the precut technique and compare different control and test sections from both projects to each other. The first formula, natural crack spacing criteria, was used so that the control sections could be analyzed side by side with the test sections. Natural crack spacing was used because it transforms data into a format comparable to the outputs for crack prediction models like the Freezing Index Model, Haas Model, Kanerva Model and TSRST models used in "Thermal Cracking Models for AC and Modified AC and Modified AC Mixes in Alaska" (Raad et al. 1997). The models previously used each differently predict the future number of transverse thermal cracks per length using various inputs and methods. Natural crack spacing is a commonly used method to quantify the number of cracks in a segment of any length. Using equation 4.1, the 9 test sections at Moose Creek and 12 test sections at Healy could be compared to the 1 control section at Moose Creek and the 4 control sections at Healy respectively. All sections can also be compared between both projects together.

$$\text{Natural Crack Spacing (ft)} = \frac{\text{Total Length of Test Section (ft)}}{\text{Total \# of Natural Cracks in Section}} \qquad (4.1)$$

By using equation 4.1, we can determine how the distance between natural cracking is affected by many different variables by looking at the distance computed for each section, and also see how the data from sections with precuts compares against sections that contain no precuts.

The second formula is equation 4.2 below which expresses the success of each precut section by evaluating the number of precuts compared to the number of precut and natural transverse cracks combined and deriving a percentage of success. This equation was one of the main criteria used in the Minnesota DOT report number 96-27 (Janisch and Turgeon 1996).

Success Rate (%) =

$$\frac{\text{\# of Precut Transverse Cracks}}{\text{\# of Precut + \# Natural Transverse Cracks}} \text{ x } 100\% \qquad (4.2)$$

By using equation 4.2, we can evaluate the success rate of each individual test section containing precuts and compare them to each other from both the Moose Creek and Healy project, and even compare them to previous experiments of the same nature like the one in Minnesota.

According to the literature review, three variables were selected in this study as critical influencing factors for precut effectiveness including precut spacing, precut depth, and pavement structure.

The first variable examined in this experiment is the distance between precuts. Using empirical evidence of natural crack spacing on roads and previous studies such as “Special Report No. 315” from Minnesota (Morchinek 1974), precut spacing intervals of 25 feet and 40 feet were chosen for the Moose Creek project as well as placing the precuts over the location of existing natural cracks. The Healy project used similar precut spacing intervals of 25 feet and 35 feet.

Another variable used is precut depth. The width and shape of all precuts installed on both projects was specified to be the same single 1/8 inch slot with variable depths. Depths used on the Moose Creek project were 0.5, 1.0, and 1.5 inches. Depths specified for the Healy project were 0.625, 1.25, and 2.0 inches. The precut depths at each project also can be related to each other through the precut depth ratio described later in equation 4.3. The three precut depths at Moose Creek and Healy correlated to three precut ratios that are directly compared between the two projects in following sections. The cut depths at Moose Creek and Healy can be compared to each other using a ratio of the precut depth to asphalt concrete thickness shown in equation 4.3 below.

Precut Depth Ratio (d/t) =

$$\frac{\text{Depth of Precut (in)}}{\text{Thickness of Asphalt Concrete (in)}} \qquad (4.3)$$

Precut depths of 0.5, 1.0, and 1.5 inches at Moose Creek have a precut depth ratio of 1/4, 1/2, and 3/4. Precut depths of 0.625, 1.25, and 2.0 inches at Healy have a precut depth ratio of 1/4, 1/2, and 4/5 (which will be counted as 3/4 for comparisons).

The third variable used for comparison is pavement structure. A total of five pavement structures were compared in this experiment. The Moose Creek project had test sections and its control section built on pavement structure I while the Healy project had test and control sections built on pavement structures II, III, IV, and V. All five pavement structures are described in Table 3.1 and are visually depicted in the Appendix.

4.2 Data Analysis for Moose Creek

Figure 4.1 and 4.2 describe the natural crack count surveys conducted at Moose Creek in 2013 and 2014 by placing the natural crack spacing derived using Equation 4.1 versus the precut depth and spacing for all 9 test sections and the control. The first, second, and third set of three bars each represent a precut depth of 0.5, 1.0 and 1.5 inches respectively. The blue, red, and green bars represent precut spacing of 25, 40, and cuts on existing cracks respectively. The dashed red line represents the natural crack spacing observed in the control section at Moose Creek. Natural crack spacing in the control section at Moose Creek was 41.3 feet in 2013 and 33.8 feet in 2014. The natural crack spacing in all test sections ranged from 50 to 145 feet in 2013 and 40 to 105 feet in 2014.

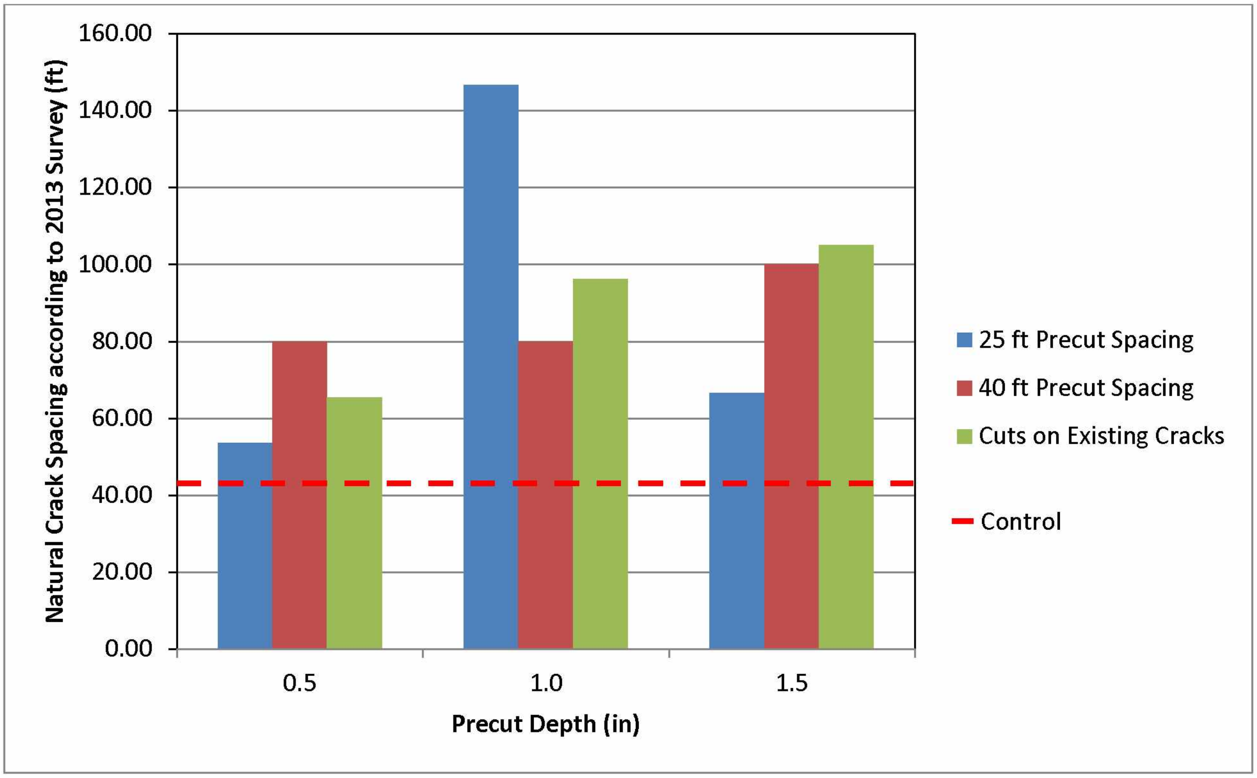

Figure 4.1 Moose Creek 2013, pavement structure I, natural crack spacing vs precut depth and spacing

All of the data shown in Figure 4.1 suggests that using the precut technique leads to longer natural crack spacing because every bar is above the control section line. In general, precuts with a depth of 1.0 or 1.5 inches performed better than the 0.5 inch cracks. The 40 foot precut spacing and cuts on existing cracks also showed a general upward trend as precut depth increased. However, it is difficult to conclude whether 25 foot precut spacing was more effective than 40 foot precut spacing because of the limited data. The "cuts on existing cracks" spacing appears to be the most effective of all the precut spacing intervals, but this spacing method works differently than the 25 and 40 foot spacing sections. Two unexpected result were discovered when looking at figure 4.2. First, for a 0.5 inch cut depth, the 40 foot precut spacing outperformed the 25 foot spacing and the cuts on existing cracks.

Second, 25 foot precut spacing performed better with a 1.0 inch depth than with a 1.5 inch depth.

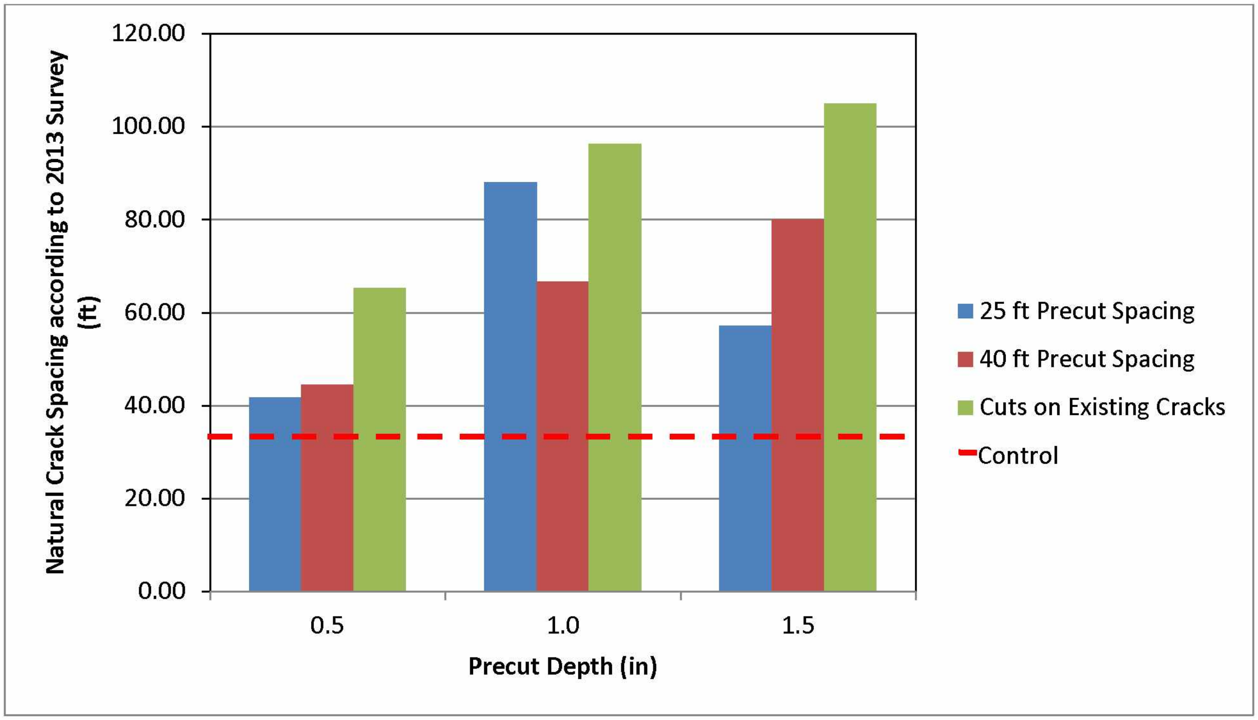

Figure 4.2 Moose Creek 2014, pavement structure I, natural crack spacing vs precut depth and spacing

Figure 4.2 shows data collected after two winters. Every precut section, bars on the graph, outperformed the control section denoted by the dashed red line. The same trends can be seen with 1.0 and 1.5 inch precut depth performing better than 0.5 inches as in 2013. A general upward trend of both the 40 foot crack spacing and cuts on existing cracks is observed with an increased crack cut depth. Only one unexpected occurrence was realized after the second year of data collection, the 25 foot precut spacing performed better than the 40 foot and cuts on existing cracks for a 1.0 inch cut depth like in the 2013 data set.

A summary for the Moose Creek data is listed below.

- All of the precut sections performed better than the control meaning the precut technique is effective in mitigating natural cracks.
- In general, deeper precuts make longer natural crack spacing, indicating less natural cracks.
- Cuts on existing cracks are the most effective. It is harder to conclude if 25 foot precut spacing is better than 40 foot spacing because out of three pairs of data (different cut

depths) the 0.5 inch depth is similar, 25 foot spacing is better for 1.0 inch depth, and 40 foot spacing is better for 1.5 inch depth.

4.3 Data Analysis for Healy

Figure 4.3 depicts the natural crack spacing versus pavement structure and precut spacing, but does not consider precut depth because all of the test and control sections placed on these pavement structures used a precut depth of 2.0 inches. For the purpose of data comparison, sections that have a natural crack spacing of 1,000 feet were recorded as such because there were zero natural cracks recorded during the survey in those test sections. The blue, red, and green bars indicate 25 and 35 foot precut spacing, and the control sections respectively. All of the test sections had a minimal amount of natural cracks ranging from 1 to 2 cracks and the controls ranged from 2 to 7 natural cracks, this information can also be observed in table 3.3.

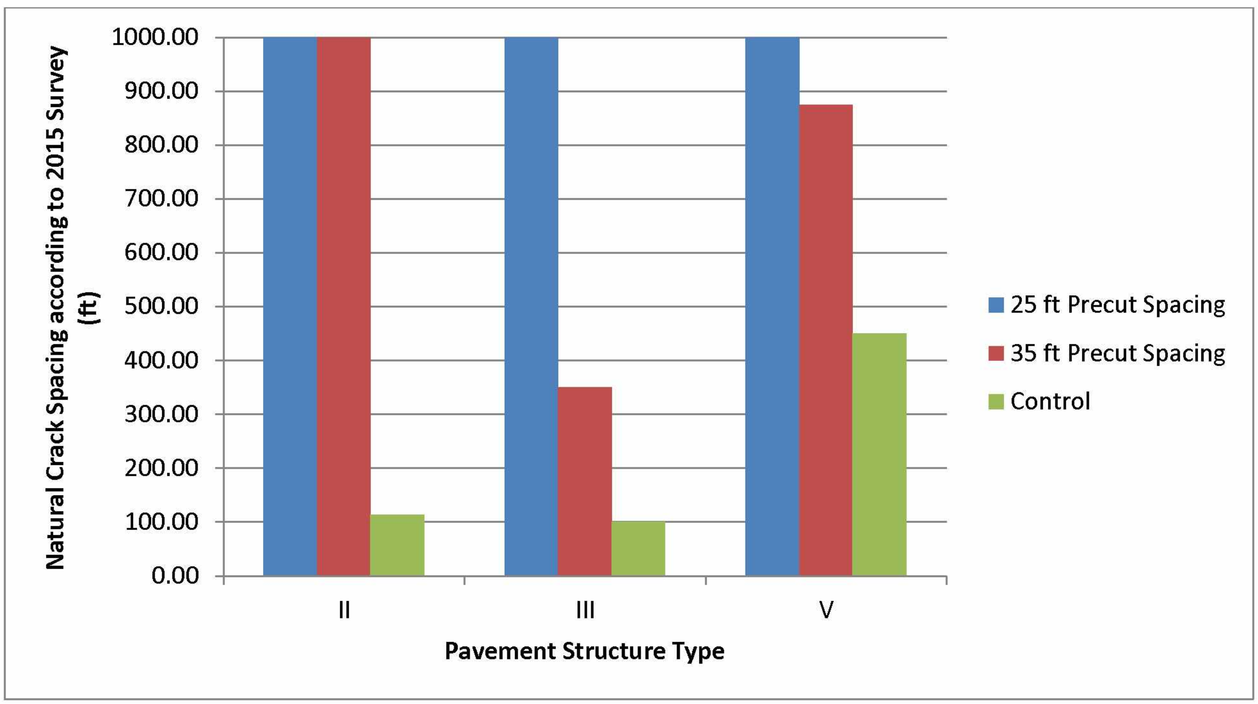

Figure 4.3 Healy pavement structure II, III, V (2 inch cut depth) natural crack spacing vs precut depth and spacing

For each pavement structure, all precut section performed better than the associated control section. The precut sections did not have a single natural crack for both 25 and 35 foot spacing, while the control had 5 leading to a natural crack spacing of about 100 feet. Structure III indicates that the 25 foot spacing is better than 35 foot with both intervals performing better than the control. The 35 foot interval section had 2 natural cracks and the control had 7 corresponding to a natural crack spacing of about 350 feet. Lastly, the 25 foot spacing was better than 35 foot for pavement structure V and both were better than the control. The 35 foot spacing interval section had 1 natural crack while the control had 2, corresponding to a natural crack spacing of 450 feet. Precut sections performed best on pavement structure II while control sections performed best on pavement structure V.

A summary for Healy Pavement Structures II, III, and V is listed below.

- All of the precut sections performed better than the control meaning the precut technique is effective in mitigating natural cracks.
- In general, the 25 foot precut spacing worked better than the 35 foot spacing.
- Pavement structure type does make a difference in overall performance.

Figure 4.4 depicts the natural crack spacing, derived using Equation 4.1, versus precut depth and spacing for 6 test sections and the control on pavement structure IV. The first, second, and third set of three bars each represent a precut depth of 0.625, 1.25 and 2.0 inches respectively. The blue and red bars represent precut spacing of 25 and 35 feet. The dashed red line represents the natural crack spacing observed in the control section. Natural crack spacing in the control section was 1,000 feet because no natural cracks were observed during the survey in 2015. The natural crack spacing in all test sections ranged from 200 to 1,000.

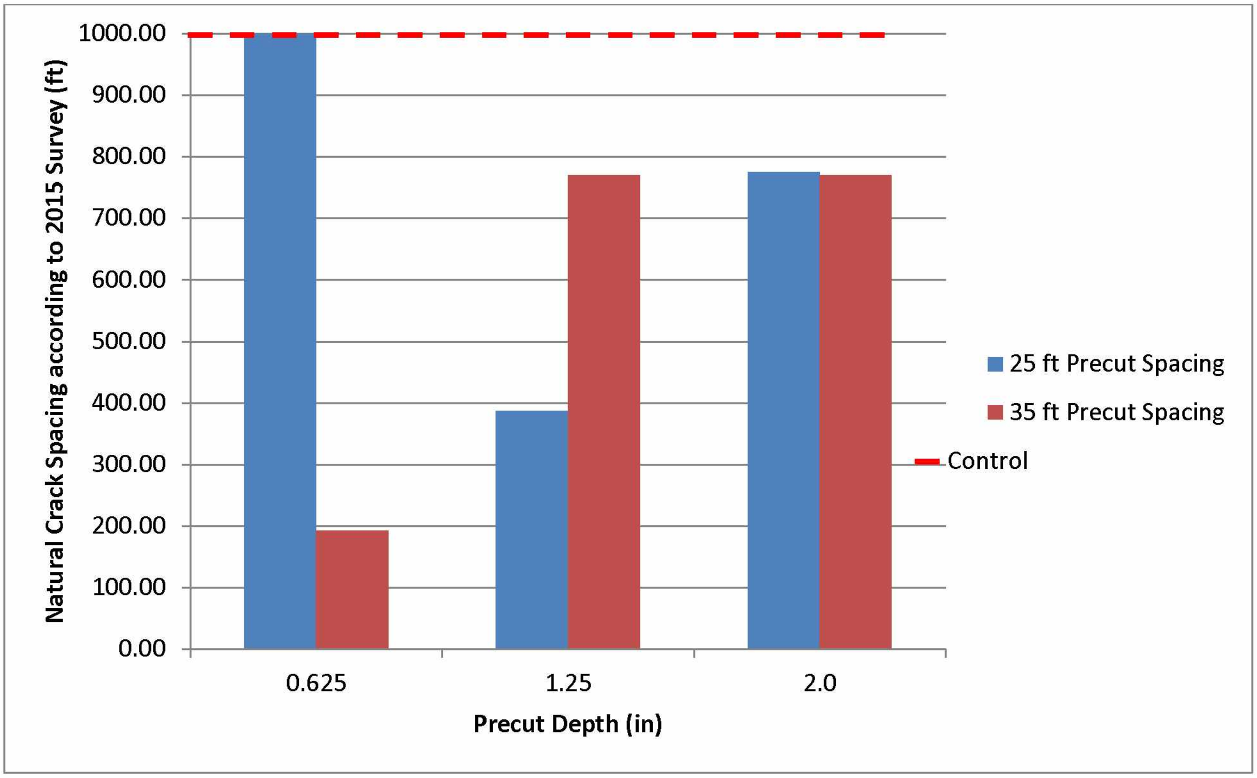

Figure 4.4 Healy pavement structure IV, natural crack spacing vs precut depth and spacing

The control in this section experienced no natural cracking. The deeper cut depths performed better than shallow ones if the section where no natural cracks formed is omitted. Similarly, 25 foot precut spacing performed better than the 35 foot spacing with deeper cut depth if the same section is omitted as before. With a 2.0 inch precut depth, the precut spacing appeared to have no effect, but more crack surveys and observations should be conducted in the future to see if that holds true for pavement structure IV.

A summary for Healy Pavement Structure IV is listed below.

- The control section performed very well so the precut technique cannot be considered effective for this pavement structure. However, only one year of data has been collected and future crack surveys may change the outcome.
- In general, deeper precut depths make longer natural crack spacing indicating less natural cracks, except for the 0.625 inch depth and 25 foot precut spacing section.
- It is difficult to determine if 25 or 35 foot precut spacing is better because 25 foot is better for one pair of data, 35 foot is better for one pair, and the third pair is similar.

4.4 Data Comparison between Projects

4.4.1 Precut Spacing

Shorter spacing mostly outperformed longer spacing. For longer precut spacing and cuts on existing cracks, natural crack spacing increased with an increased cut depth. Most data from Moose Creek had a natural crack spacing ranging from 40-100 feet, the only comparable spacing at Healy was from the control sections on pavement structures II and III.

Figure 4.5 shows the frequency for how often shorter or longer precut spacing intervals are more effective. Nine pairs of data were compared for precut spacing. A pair is defined as two test sections that have the same precut depth and pavement structure but have different precut spacing. Moose Creek had 3 pairs of data on pavement structure I (Figure 4.1), Healy had 3 pairs of data on pavement structure IV (Figure 4.4) and 1 pair each on pavement structures II, III, and V (Figure 4.3).

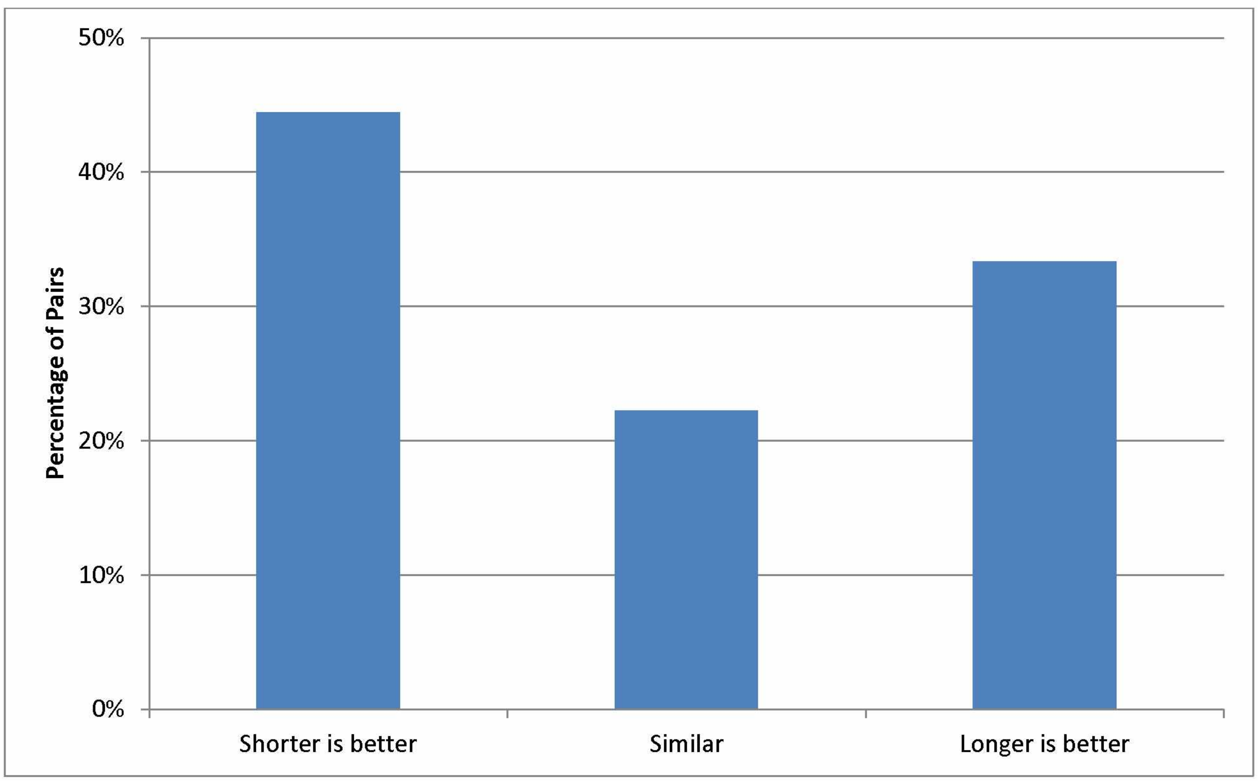

Figure 4.5 Comparison of precut spacing effect

Out of 9 total pairs compared, 4 pairs show that short precut spacing is better, 2 pairs show that shorter and longer precut spacing results are similar, and 3 pairs show that longer precut spacing is better. From figure 4.5, one can determine that shorter precut spacing is slightly better than longer at this point in time, but long-term monitoring is recommended for further interpretation.

4.4.2 Precut Depth

Generally speaking, deeper cut depths make longer natural crack spacing, indicating less natural cracks. This can be seen in both Moose Creek and Healy projects, with a few exceptions as stated before.

Figure 4.6 shows how many times each of the three different precut depth ratios was most effective. A precut depth ratio was considered most effective by comparing the three ratios for a particular spacing and pavement structure, and choosing the ratio (or depth) that had the longest natural crack spacing. Moose Creek data from 2013 was used for comparison with Healy because Healy only had one year of data available. A total of 5 pairs of data were combined to create Figure 4.6, these pairs included 25, 35, and cuts on existing crack spacing for Moose Creek from figure 4.1 and 25 and 40 foot spacing for Healy from figure 4.4.
A depth ratio of 1/4 was most effective one time, for 25 foot precut spacing at Healy. 1/2 depth ratio was most effective three times; 35 foot precut spacing at Healy, 25 foot precut spacing at Moose Creek, and 40 foot precut spacing at Moose Creek. 3/4 depth ratio was most effective three times; 35 foot precut spacing at Healy, 40 foot precut spacing at Moose Creek, and cuts on existing cracks at Moose Creek. Greater depth ratios tend to be most effective more often.

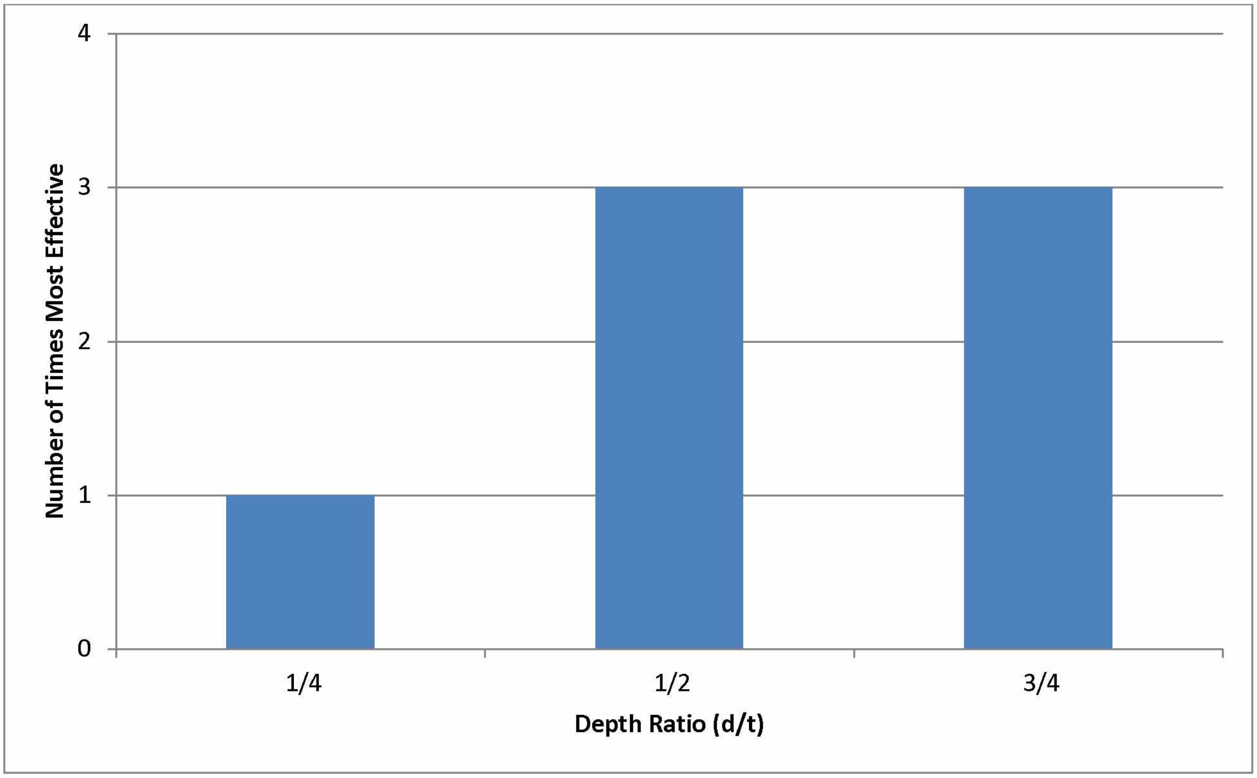

Figure 4.6 Comparison of precut depth ratio effect

4.4.3 Comparison with Success Rate

Success rates for all Moose Creek and Healy test sections are shown in Figure 4.7. The blue bars represent data from the 2013 Moose Creek test section crack survey compiled utilizing equation 4.2. The red bars represent the data from 2014 from the Moose Creek test sections using equation 4.2. The green bars represent data from the Healy project collected during the crack survey in 2015 using equation 4.2. Control sections could not be included in this data set because there were no precuts, an essential input for using equation 4.2.

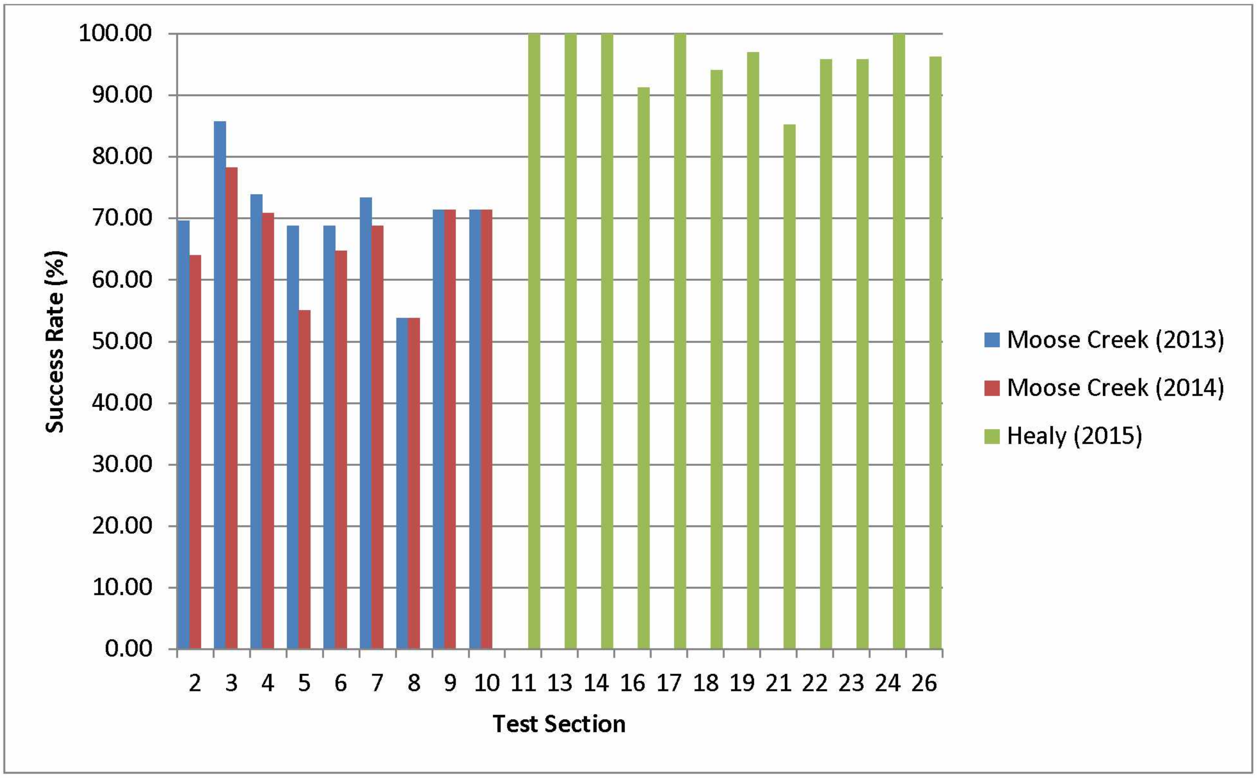

Figure 4.7 Success rate for all test sections (no controls)

The average rate of success at Moose Creek for the 2013 and 2014 survey were 71% and 66% respectively. The average rate of success for the Healy project was 96%. Section 3, which had a precut depth of 1.0 inch and spacing of 25 foot performed the best at Moose Creek with a success rate of 86% in 2013 and 78% in 2014. Section 8, which had a precut depth of 0.5 inches and precut spacing that varied, because the cracks were placed over existing cracks, performed the worst at Moose Creek according to the success criteria with a rate of 54% both years. Generally the success rate dropped from the first year to the second except in sections 8, 9, and 10 where precuts were placed over existing cracks. The lowest success rate recorded for Healy was test section 21 with a precut depth of 0.625 inches and spacing of 35 feet, the shallowest cut section and longest spacing respectively. Section 21 was also situated on pavement structure IV.

Healy outperformed Moose Creek in all but one instance where the worst success rate from Healy was slightly less than the best success rate from Moose Creek from the first year of data. It is important to note that the results from these two projects can be compared with similar experiments performed in other northern region states conducting similar studies. The

Minnesota Department of Transportation (Mn/DOT) put together a saw and seal advisory committee that concluded a success rate of 85% or greater meant the project was successful (Janisch and Turgeon 1996). 50 test sections with different parameters were constructed and monitored for over 4 years. Of the 50 test sections, more than 38 had a success rate above 85% while 12 sections fell below the threshold (Janisch and Turgeon 1996). Comparatively, only 1 section from Moose Creek during the first year would be considered successful according to the 85% success rate standard, and no sections would be successful after only 2 years. However, all of the sections from Healy would be considered successful so far. To truly compare the Moose Creek and Healy sections with the (Janisch and Turgeon 1996) test sections, similar precut depth, spacing, and pavement structures would need to also be considered as well as waiting another 2 years for Moose Creek and 3 years for Healy for similarly aged pavements. (Janisch and Turgeon 1996) also used a saw and seal method whereas this study only “sawed” or used precuts without sealing.

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Chapter 5 Economic Analysis

5.1 Cost for Crack Repair in Northern Region

ADOT&PF Northern Region maintenance division typically spends in the range of $1.30 to $2.20 per linear foot of crack for crack sealing. This range depends mostly on location of where the crack sealing is to take place. If the cracks are near the maintenance station and do not involve heavy traffic control, the price will be on the lower end. If the cracks are far from the station where maintenance crews must travel to on per diem or if the roads have high traffic loadings, the cost will near the high mark. This information was gathered from personal conversation with ADOT&PF Maintenance and Operations Division in October of 2015. For this experiment, the cost for ADOT&PF to repair cracks at Moose Creek will be $1.50 per linear foot due to traffic loadings and $1.30 per linear foot in Healy for the economic analysis. The cost is higher for Moose Creek due to the higher traffic count, approximately 925 AADT for the inside lane and 2,806 for the outside lane versus 1,150 for Healy. ADOT&PF also routs existing cracks and cleans them with a hot lance, which is something that not every department or contractor does.

A local Alaskan contractor owner quoted the price of sealing cracks if they were to bid on a crack sealing project. The contractor, who wished to remain unnamed, quoted a lower price of $3.00 up to $6.00 per linear foot. With a shortage in ADOT&PF maintenance crews and money, hiring a contractor may be the only method of crack repair in some instances (allows the use of a different funding source), so prices of $3.50 and $3.00 per linear foot of crack sealing for Moose Creek and Healy respectively were used for the economic analysis. The lower end of the price range was chosen because this type of maintenance could be lumped with other maintenance projects reducing the cost through economies of scale, also the lower price range leads to a more conservative estimate of the cost for maintenance.

5.2 Cost to Install Precuts

The cost to install precuts was difficult to establish due to limited data between the two projects. The Moose Creek project was bid as a lump sum change order and the Healy project included the cost of precuts as subsidiary to the hot mix asphalt pay item which means the actual cost could not be determined.

At Moose Creek, a total of 111 precuts were installed with a width of 38 feet each for a total cost of $9,808.00 which was the lump sum cost for the work to be added to the Moose Creek project by change order during construction. Using the number of precuts, width of pavement and total cost, on average, precuts at Moose Creek cost $2.33 per linear foot. The cost for precut depth could not be determined without knowing the amount of time that each depth took to install.

5.3 Assumptions

Many assumptions were made in order to compare the cost of precuts with the cost of maintenance. The assumptions are listed below:

- Precuts never need to be maintained.
- For Method 1, 100% of natural cracks formed after one year will need to be sealed, the same number of natural cracks will form over the lifetime of the pavement and need maintenance at 7 and 14 years. Figure 5.9 in the report "Low Temperature Cracking of Modified AC Mixes in Alaska" Shows that most natural cracking occurs in the first 7 years of a pavement's life (Raad et al. 1997). This is why half of the cracks produced are assumed to form in year one with another 100% in the future and why the sealing activities will occur at 7 and 14 years in this analysis. The Haas Model, Kanerva Model and TSRST models (Raad et al. 1997) also show a general natural cracking frequency that is greater in the earlier years, the future predicted cracks for method 1 was developed for this analysis to try and mirror those trends.
- Installation costs were derived only from the Moose Creek project.
- For Method 1, only the first year of data collection was used for both projects.
- All precut depths cost the same amount per linear foot to install.
- The lower maintenance cost quoted by the contractor was used for a conservative estimate.

5.4 Cost Comparison

Two methods were used to evaluate the cost effectiveness of the precut technique. Method 1 compares the cost to install precuts and the maintenance cost to seal cracks that develop in the precut section versus the cost to seal cracks that develop in the control section. Future natural cracks are predicted using the assumption above and sealing activities occur at years 1, 7, and 14. Method 1 only compares data from the first year of data collection at each experimental site.

Method 2 compares the same costs as Method 1; however, instead of predicting future cracks, the number of natural cracks necessary to form in the control section to equal the cost of installing a precut section is computed. Sealing activities in Method 2 occur on an annual basis. Method 2 plots actual normalized data from both years of data collection at Moose Creek and one year from Healy.

5.4.1 Method 1

The total cost to install and maintain each precut section was compared to the cost that maintaining the control sections would incur. If the cost to install and maintain the precut section was lower than the control section with the same pavement structure, it was considered cost effective. Installation and future maintenance costs were determined using equations 5.1 through 5.5 below. Cost per foot for installation and maintenance were described previously in sections 5.1 and 5.2.

Installation Cost ($) =

$$\text{Total Length of Precuts in Section (ft) x Cost per Foot (\$/ft)} \tag{5.1}$$

Installation Cost per 1,000 foot ($/ft) =

$$\frac{\text{Instalation Cost (\$)}}{\text{1,000 (ft)}} \tag{5.2}$$

Maintenance Cost ($) =

$$\frac{\text{\# Natural Cracks x Width of Pavement (ft) x Maintenance Cost per Foot (\$/ft)}}{(1+0.04)^{1}} +$$

$$\frac{\text{\# Natural Cracks x Width of Pavement (ft) x Maintenance Cost per Foot(\$/ft)}}{(1+0.04)^{7}} \text{ x } 0.5 +$$

$$\frac{\text{\# Natural Cracks x Width of Pavement (ft) x Maintenance Cost per Foot(\$/ft)}}{(1+0.04)^{14}} \text{ x } 0.5 \qquad (5.3)$$

Maintenance Cost per 1,000 foot ($/ft) =

$$\frac{\text{Maintenance Cost (\$)}}{\text{1,000 (ft)}} \qquad (5.4)$$

Total Cost ($) =

$$\text{Installation Cost per 1,000 foot} + \text{Maintenance Cost per 1,000 foot} \qquad (5.5)$$

The number of natural cracks after one year was used as the projected number of additional cracks that will need to be sealed during the lifetime of the pavement. 100% of natural cracks after one year would be maintained that year. 50% of the additional cracks to maintain will occur at 7 years and the other 50% will be maintained at 14 years. All maintenance costs are reduced by a discount factor with a 4% interest rate to convert all costs to net present value (NPV). A discount rate of 4% was used because that is what ADOT&PF uses for long term pavement equations. Only 14 years of cracking was used because after that point, ADOT&PF may look to repave or expend resources for maintenance, also thermal cracking will have been well established at that point, and other distress factors such as fatigue cracking will be occurring.

Figures 5.1 and 5.2 show cash flow diagrams for the economic analysis presented. The control section includes one more cost, the initial cost for installation at year zero. Otherwise, the two graphs show the same costs associated with maintaining the pavement through crack sealing activities at year 1, 7, and 14. If the NPV (total cost) for a precut section is less than the NPV for the control section on the same pavement structure, then the precut section is considered cost effective preliminarily.

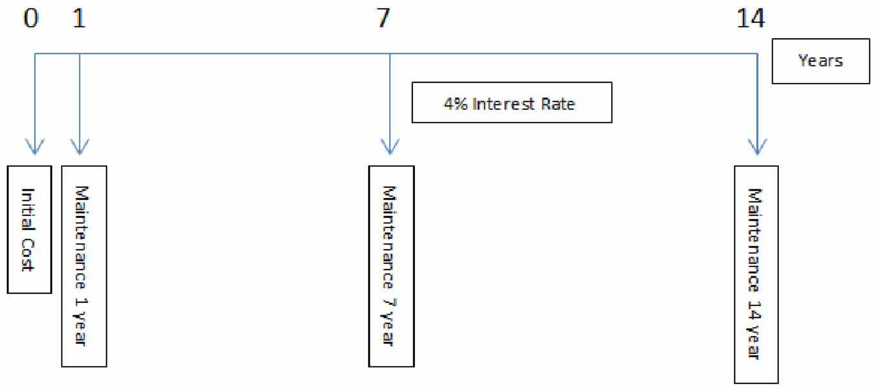

Figure 5.1 Cash flow diagram for precut section, NPV (total cost)

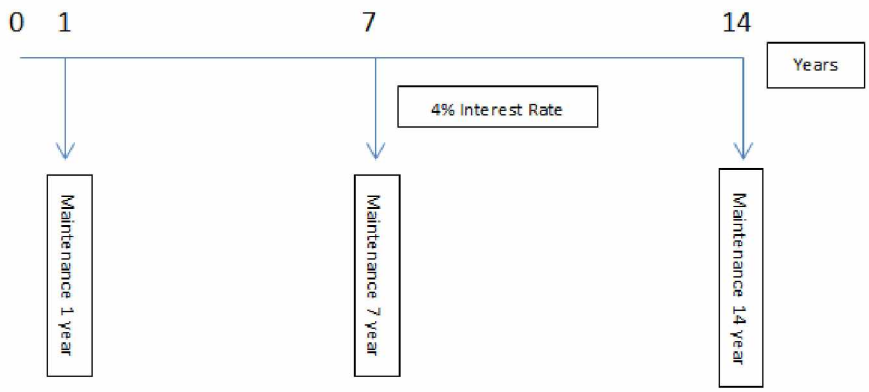

Figure 5.2 Cash flow diagram for control section, NPV (total cost)

Table 5.1 shows all 26 test and control sections, the installation cost for each section, the installation cost for an equivalent section of 1,000 foot length, maintenance cost for the section, maintenance for a similar section of 1,000 foot length, and the total cost for a 1,000 foot section. The grey rows indicate a control section and the white rows are test sections, all sections can be referred back to the project description sections in Chapter 3. If a section has a total cost lower than the control section with the same pavement structure, then it would be considered cost effective according to this analysis. However, future evaluations should be conducted due to the limited amount of data for the cost to install precuts, cost to maintain natural cracks, and the number of natural cracks that need to be maintained.

Table 5.1 shows that all sections at Moose Creek, except for 2 and 4 were cost effective. This analysis is based on extremely limited data with many assumptions. The table will give an idea of the order of magnitude between utilizing the precut technique or maintaining naturally occurring cracks. None of the Healy test sections were cost effective using Method 1.

Table 5.1 Cost effectiveness analysis, Method 1

Project	Section	Installation Cost	Installation Cost per 1,000 foot	Maintenance Cost	Maintenance Cost per 1,000 foot	Total Cost
Moose Creek	1	$ -	$ -	$ 6,938.28	$ 5,256.27	$ 5,256.27
	2	$ 1,413.77	$ 3,770.04	$ 1,517.75	$ 4,047.33	$ 7,817.37
	3	$ 1,590.49	$ 3,614.74	$ 650.46	$ 1,478.33	$ 5,093.07
	4	$ 1,502.13	$ 3,755.32	$ 1,300.93	$ 3,252.32	$ 7,007.63
	5	$ 971.96	$ 2,429.91	$ 1,084.11	$ 2,710.27	$ 5,140.18
	6	$ 971.96	$ 2,429.91	$ 1,084.11	$ 2,710.27	$ 5,140.18
	7	$ 971.96	$ 2,429.91	$ 867.28	$ 2,168.21	$ 4,598.12
	8	$ 618.52	$ 1,577.86	$ 1,300.93	$ 3,318.69	$ 4,896.56
	9	$ 883.60	$ 2,295.07	$ 867.28	$ 2,252.69	$ 4,547.76
	10	$ 883.60	$ 2,103.82	$ 867.28	$ 2,064.96	$ 4,168.78
Healy	11	$ 2,139.25	$ 3,889.55	$ -	$ -	$ 3,889.55
	12	$ -	$ -	$ 1,084.11	$ 1,901.94	$ 1,901.94
	13	$ 1,581.19	$ 2,823.55	$ -	$ -	$ 2,823.55
	14	$ 2,697.32	$ 3,853.31	$ -	$ -	$ 3,853.31
	15	$ -	$ -	$ 1,517.75	$ 2,168.21	$ 2,168.21
	16	$ 1,953.23	$ 2,790.33	$ 433.64	$ 619.49	$ 3,409.82
	17	$ 2,976.35	$ 3,840.45	$ -	$ -	$ 3,840.45
	18	$ 3,497.21	$ 4,512.53	$ 433.64	$ 559.54	$ 5,072.07
	19	$ 3,571.62	$ 4,608.54	$ 216.82	$ 279.77	$ 4,888.31
	20	$ -	$ -	$ -	$ -	$ -
	21	$ 2,567.10	$ 3,333.90	$ 867.28	$ 1,126.34	$ 4,460.24
	22	$ 2,567.10	$ 3,333.90	$ 216.82	$ 281.59	$ 3,615.48
	23	$ 2,567.10	$ 3,333.90	$ 216.82	$ 281.59	$ 3,615.48
	24	$ 4,129.68	$ 4,588.54	$ -	$ -	$ 4,588.54
	25	$ -	$ -	$ 433.64	$ 481.82	$ 481.82
	26	$ 2,418.28	$ 2,763.75	$ 216.82	$ 247.80	$ 3,011.55

5.4.2 Method 2

Future natural cracking is difficult to predict with little data on actual asphalt properties and only one and two years of data at the experimental sites so another cost effective analysis was evaluated. The following analysis using Method 2 aims to determine the net gain of thermal cracks in the control sections versus the precut sections for a section to be cost effective. A net gain of one crack would mean 1 natural thermal crack formed in the control section while 0 formed in the precut section, or 2 formed in the control while 1 formed in the precut section. After the net gain of cracks required for cost effectiveness is determined, the number is divided over 14 years and plotted linearly with interest. Actual data from field surveys are then normalized and compared to the net gain required. Table 5.2 shows values computed and if the current precut sections are on track for being cost effective at this time. Lastly, ADOT&PF designed the pavement at Moose Creek and Healy for a 20 year life, but 14 years will be used for comparison to Method 1. The following equations are used for this analysis. Equation 5.6 determines the net number of cracks that would be necessary to form in the control section versus precut section for the section to be considered cost effective, it also normalizes sections to 1,000 foot length. Equation 5.7 is used to determine how many cracks per year for 14 years would have to develop in the control section versus the precut section for cost effectiveness. Equation 5.8 puts the number of cracks required each year into net present value. Equation 5.9 takes the recorded data and determines the net amount of cracks formed for years one and two at Moose Creek, and for year one at Healy and also records this number of cracks in net present value terms. Equation 5.9 also normalizes the amount of cracks gained in control versus precut sections to 1,000 foot length.

Natural Cracks Required for Cost Effectiveness (#) =

$$\frac{\text{Installation Cost for Precut Section(\$)}}{\text{Width of Pavement (ft) x Maintenance Cost (\$/ft)}} \text{ x } \frac{\text{1,000 ft}}{\text{Precut Section Length (ft)}} \tag{5.6}$$

Natural Cracks Required per Year (#/year) =

$$\frac{\text{Natural Cracks Required for Cost Effectiveness (\#)}}{\text{14 Years}} \tag{5.7}$$

Natural Cracks Required at Year n (#) =

$$\text{Net Natural Cracks Required per Year (\#/year) x } (1.04)^{\wedge}\text{n} \tag{5.8}$$

Actual Cracks at Year n (#) =

$$[(\text{\# Cracks Formed in Control in year n}) \text{ x } \frac{\text{1,000 ft}}{\text{Control Length}} - (\text{\#Cracks Formed in Precut Section in year n}) \text{ x } \frac{\text{1,000 ft}}{\text{Precut Section Length}}] \,/\, (1.04)^{\wedge}\text{n} \tag{5.9}$$

Table 5.2 displays the results of equations 5.6 through 5.9, the “Cost Effective to Date?” column shows if a particular section is on track, currently, to be cost effective. For the first year of data collection, a section is cost effective if “Actual Cracks at Year 1” is greater than “Natural Cracks Required at Year 1” (orange cells). For the second year of data collection, at Moose Creek, a section is cost effective if the “Combined Actual Cracks Year 1 & 2” is greater than “Combined Natural Cracks Required Year 1 & 2” (blue cells).

Table 5.2 Cost effectiveness analysis, Method 2

Project	Section	Natural Cracks Required for Cost Effectiveness	Natural Cracks Required per Year	Natural Cracks Required at Year 1	Natural Cracks Required at Year 2	Combined Natural Cracks Required Year 1 & 2	Actual Cracks at Year 1	Actual Cracks at Year 2	Combined Actual Cracks Year 1 & 2	Cost Effective to Date?
Moose Creek	2	28.35	2.02	2.11	2.19	4.30	5.36	-0.03	5.33	Yes
	3	27.18	1.94	2.02	2.10	4.12	16.75	0.70	17.45	Yes
	4	28.24	2.02	2.10	2.18	4.28	8.89	2.59	11.48	Yes
	5	18.27	1.30	1.36	1.41	2.77	11.29	-4.34	6.95	Yes
	6	18.27	1.30	1.36	1.41	2.77	11.29	2.59	13.88	Yes
	7	18.27	1.30	1.36	1.41	2.77	13.69	2.59	16.29	Yes
	8	11.86	0.85	0.88	0.92	1.80	8.59	4.90	13.50	Yes
	9	17.26	1.23	1.28	1.33	2.62	13.32	4.90	18.22	Yes
	10	15.82	1.13	1.18	1.22	2.40	14.15	4.90	19.06	Yes
Healy	11	13.39	0.96	0.99			8.43			Yes
	13	23.53	1.68	1.75			8.43			Yes
	14	32.11	2.29	2.39			9.62			Yes
	16	23.25	1.66	1.73			6.87			Yes
	17	32.00	2.29	2.38			0.00			No
	18	32.00	2.29	2.38			-2.48			No
	19	32.00	2.29	2.38			-1.24			No
	21	23.15	1.65	1.72			-5.00			No
	22	23.15	1.65	1.72			-1.25			No
	23	23.15	1.65	1.72			-1.25			No
	24	31.86	2.28	2.37			2.14			No
	26	19.19	1.37	1.43			1.04			No

Figures 5.3 through 5.5 show the data from Table 5.2. Figures were not produced for every section as all of the data can be interpreted using Table 5.2.

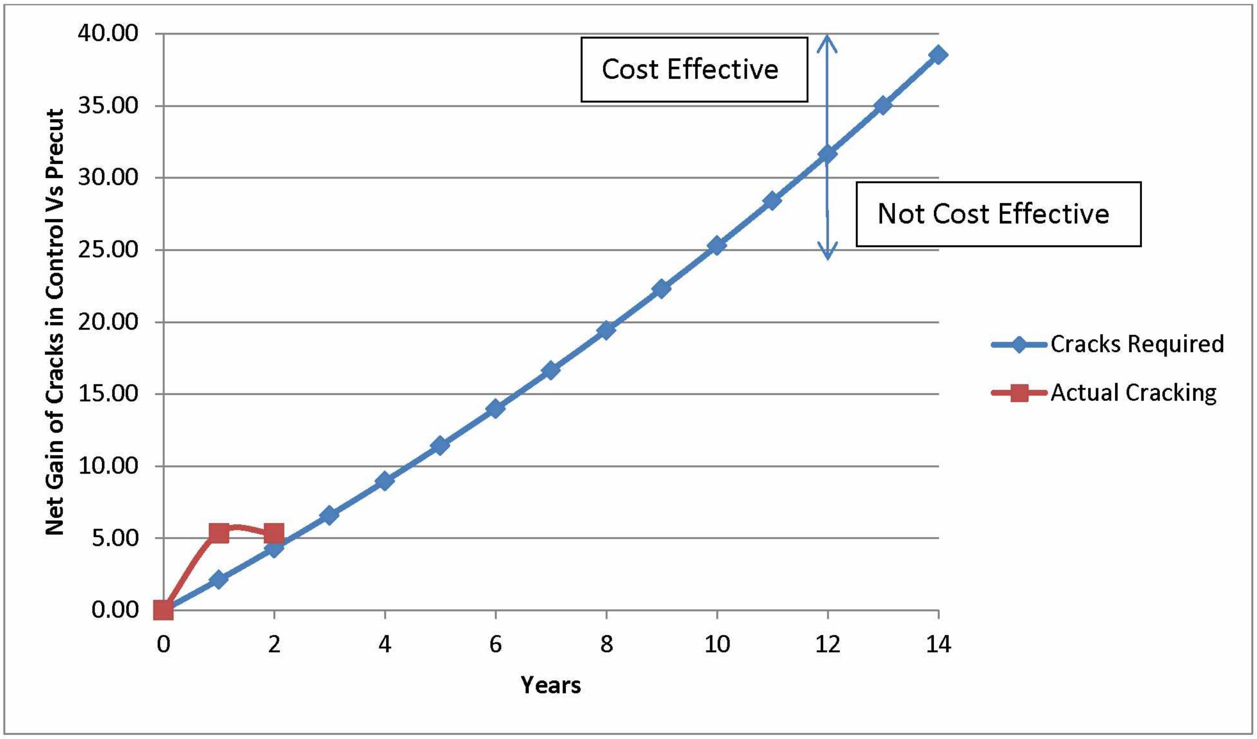

Figure 5.3 Net gain of natural cracks in control over precut versus time for Section 2

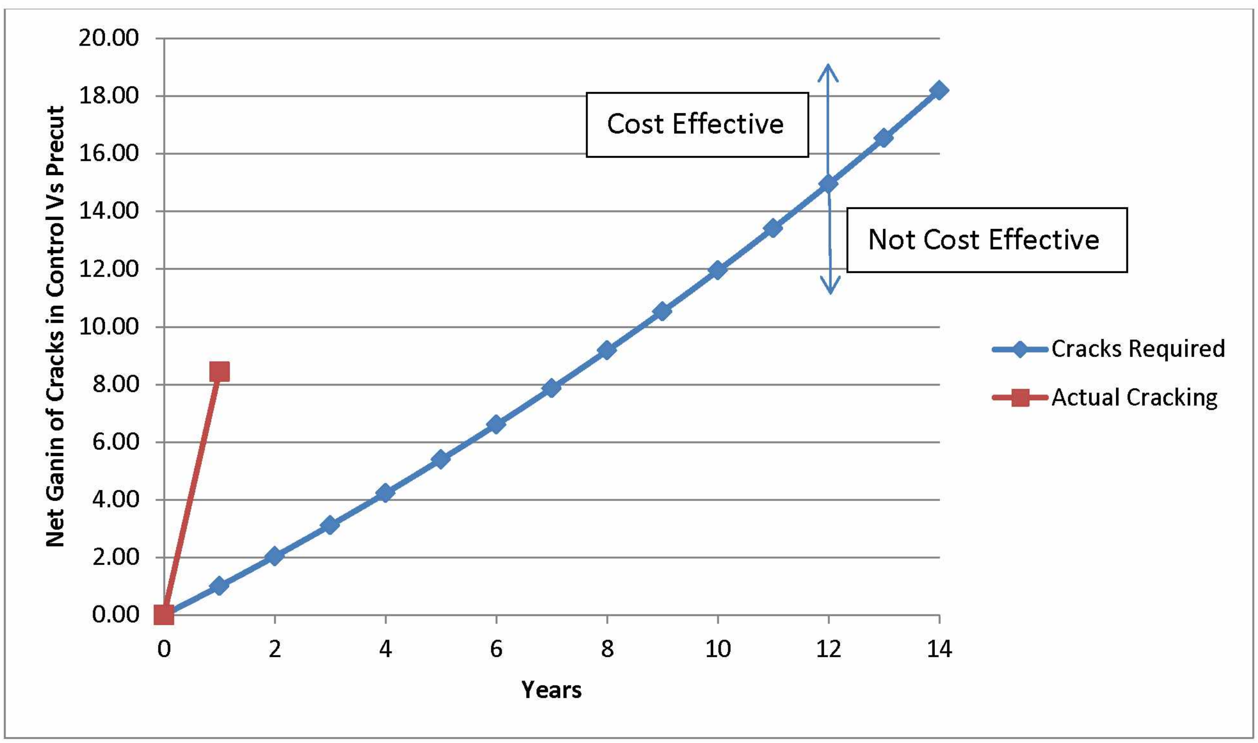

Figure 5.4 Net gain of natural cracks in control over precut versus time for Section 11

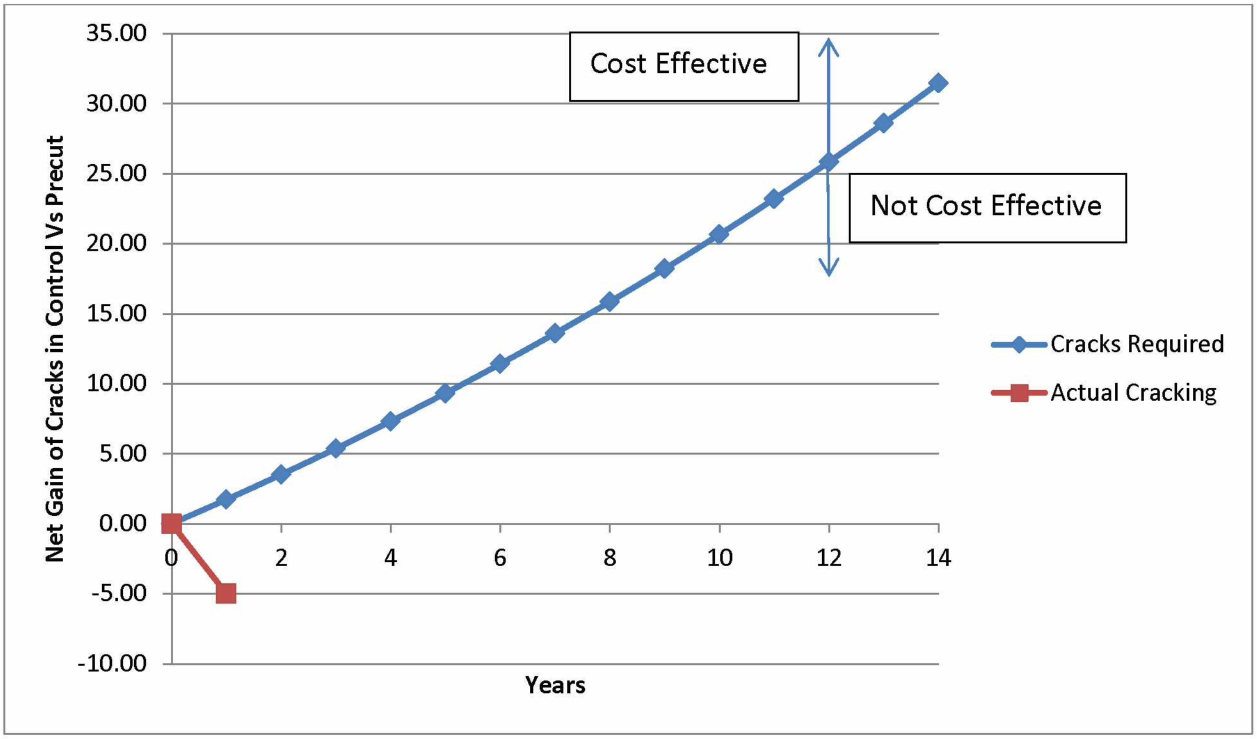

Figure 5.5 Net gain of natural cracks in control over precut versus time for Section 21

Table 5.2 showed that all of the Moose Creek sections and sections 10, 11, 13, 14, and 16 at Healy are currently cost effective. These results are slightly different than the previous cost effective analysis that showed none of the Healy sections being cost effective. Only time and future crack surveys will be able to determine if the sections investigated and cost effectiveness prediction methods used will hold true.

Figures 5.3 through 5.5 graphically depict actual natural cracking next to a linear equal value, or equilibrium, line. If the Actual natural cracking is above the equal value line, then the precuts are considered cost effective, if the actual cracking falls below the equal value line, then the precuts are not considered cost effective. This graphic representation is very helpful because it shows how future cracking may or may not affect if a section is cost effective or not. The three sections represented above in figures 5.3 through 5.5 show two sections that are cost effective, 2 and 11; and one section that is not cost effective, 21.

Chapter 6 Conclusions and Recommendations

6.1 Conclusions

Precutting technology has been shown to work well in cases where roadway construction has included placement of at least several feet of new material. This has been demonstrated in Minnesota as well as by the 30-year-old test section at Fairbanks, Alaska and is reinforced by the fact that pavement sections II and V performed very well in Healy.
With the caveat that the Moose Creek experimental section reported herein has been monitored for only two years and the Healy experimental section only one, this research tentatively indicates that precutting can significantly benefit the thermal crack performance of any new road project.

In Healy, the best sections were built on pavement structures that included several feet of new material and reinforcing fabrics. In general, deeper cuts and shorter spacing provided the best results in the field, but the shorter spacing was ultimately less cost effective. Although many sections were preliminarily less cost effective, intangibles exist like driver comfort when riding over precuts versus natural cracks and the overall "professionally finished look" of the road to the public.

Precut technology is still in a very young stage of research but has the potential to become as important as joints in Portland cement concrete. Continuation of research in the field of precuts on asphalt concrete is paramount to discovering what could be a massive cost savings for roads in cold climates. This study has shown that precutting is effective for almost every test section examined at Moose Creek and Healy. Deeper precuts, shorter spacing, and larger, more reinforced pavement structures work best when utilizing the precut technique. More information will be needed for absolute determination of cost effectiveness, but preliminary analysis of cost shows some sections are on track to be cost effective and others may become effective in the future. The precut technique is a very promising tool for use on future road construction projects.

6.2 Recommendations

The most important recommendation is to continue monitoring all of the control and test sections at Moose Creek and Healy of the life of the pavement and perform accurate crack surveys every year or few years. Monitoring these sections for the life of the pavement and recording the number of natural cracks as well as precuts that require maintenance in the future is necessary for performing more accurate cost effective analyses. Future crack surveys will also provide critical values that can be input into equations and graphs presented in this thesis and provide more real data and less predicted values. More comprehensive data for both installing precuts and maintaining natural cracks in similar locations would also be very beneficial in determining the effectiveness of the precut technique. In order to acquire more cost data on installing precuts, more test sections should be constructed with accurate cost estimates recorded for each test section, factoring in any additional costs for depth of precuts. More test sections should not only be constructed to acquire more cost data, but also to compare more precut depth, spacing, and pavement structure types. The success of precuts over existing cracks should be incorporated into future projects to verify the success from the sections at Moose Creek. More research could also be directed towards the vast amount of precuts that are already in place at the Fairbanks International Airport as well.

Another variable that may be considered in future projects could include differing subgrade conditions, not just the pavement structure, but what the structure is sitting above. Variations in the layers of the pavement structure could also be noted for future research especially in the most important layer, the asphalt concrete. Test sections using different types of asphalt binder; for instance, the use of performance grade PG 52-40 (polymer-modified) instead of the neat, unmodified PG 52-28 used on most of the rural roadways in interior Alaska, may also lead to more success and a more cost effective means of reducing future maintenance costs associated with transverse thermal cracking.

Monitoring the effects of sealing versus not sealing natural cracks would give an idea of how much maintenance is actually required before constructing expensive precuts. The report on “Evaluating the Need to Seal Thermal Cracks in Alaska’s Asphalt Concrete Pavements” is a first look at the effects of sealing versus not sealing natural thermal cracks (McHattie et al.

2013). It may be important to monitor if precuts will ever require sealing as well because the lack of a need to was a large assumption in the economic analysis.

In conclusion, we must continue monitoring existing test sections, construct new test sections with different variable for optimization, and monitor crack maintenance and precut installation costs in the future. Continued crack surveys will fill data gaps in this thesis and provide accurate empirical evidence of precut technique effectiveness. Thus far, the precut technique appears effective, but only future data and studies will verify the results in this thesis.

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Appendix

Pavement structures for Moose Creek and Healy

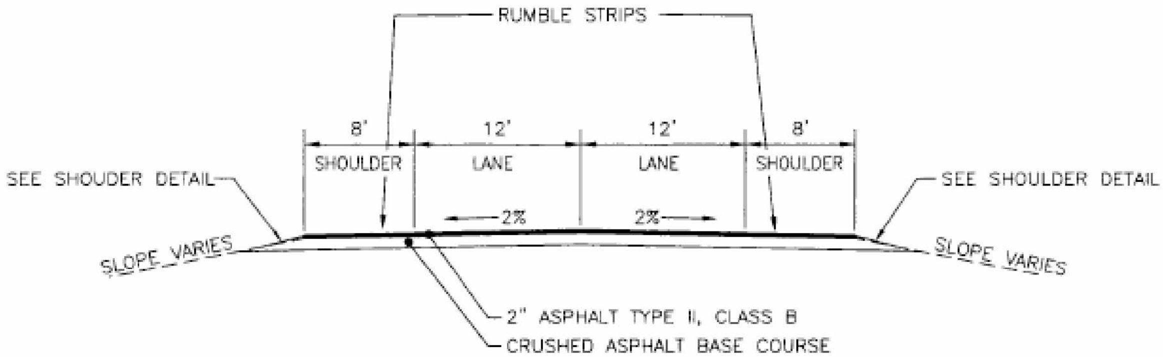

Figure A.1 Moose Creek, pavement structure I (image courtesy ADOT&PF)

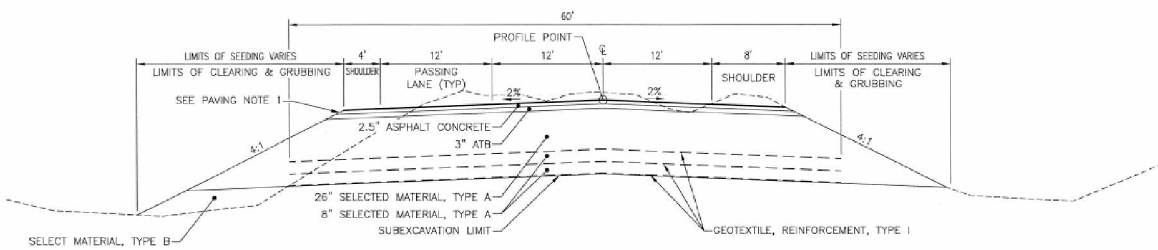

Figure A.2 Healy, pavement structure II (image courtesy ADOT&PF)

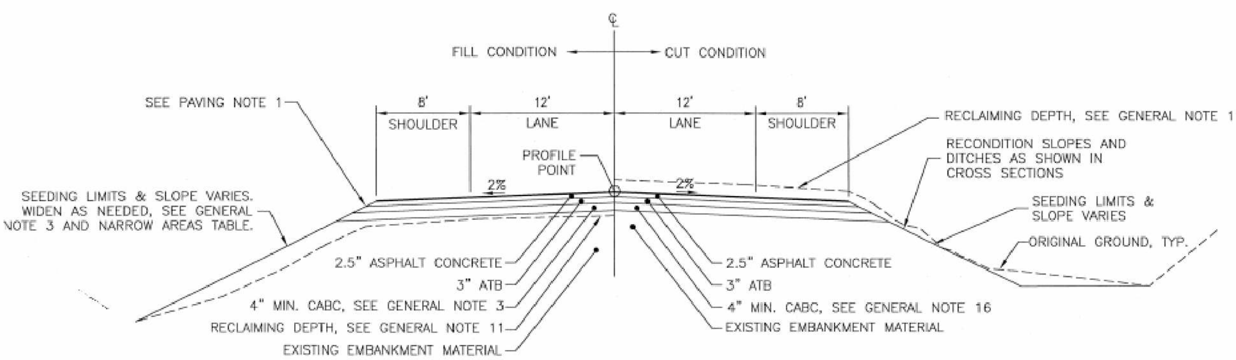

Figure A.3 Healy, pavement structure III (image courtesy ADOT&PF)

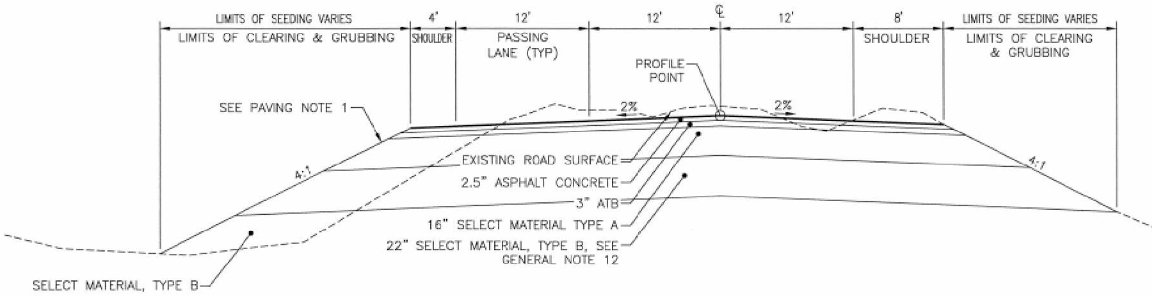

Figure A.4 Healy, pavement structure IV (image courtesy ADOT&PF)

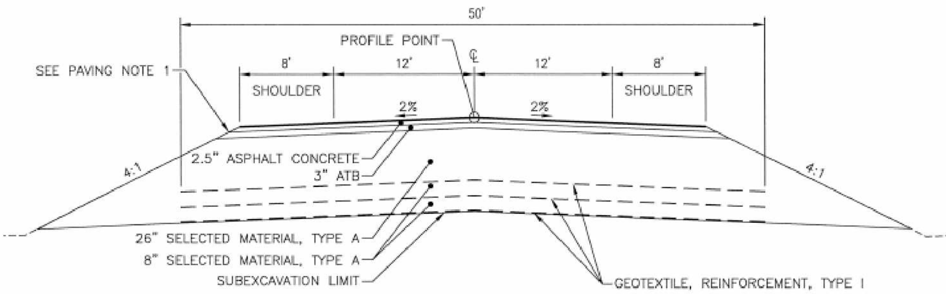

Figure A.5 Healy, pavement structure V (image courtesy ADOT&PF)